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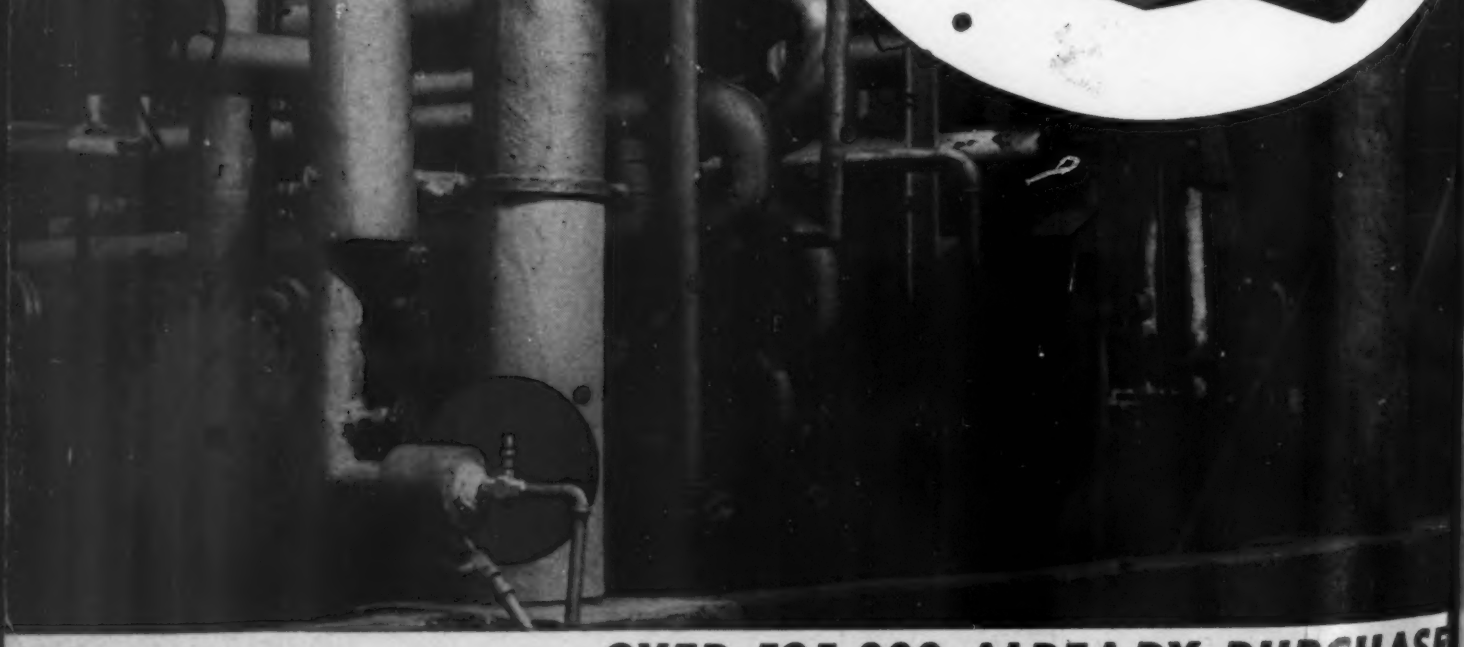

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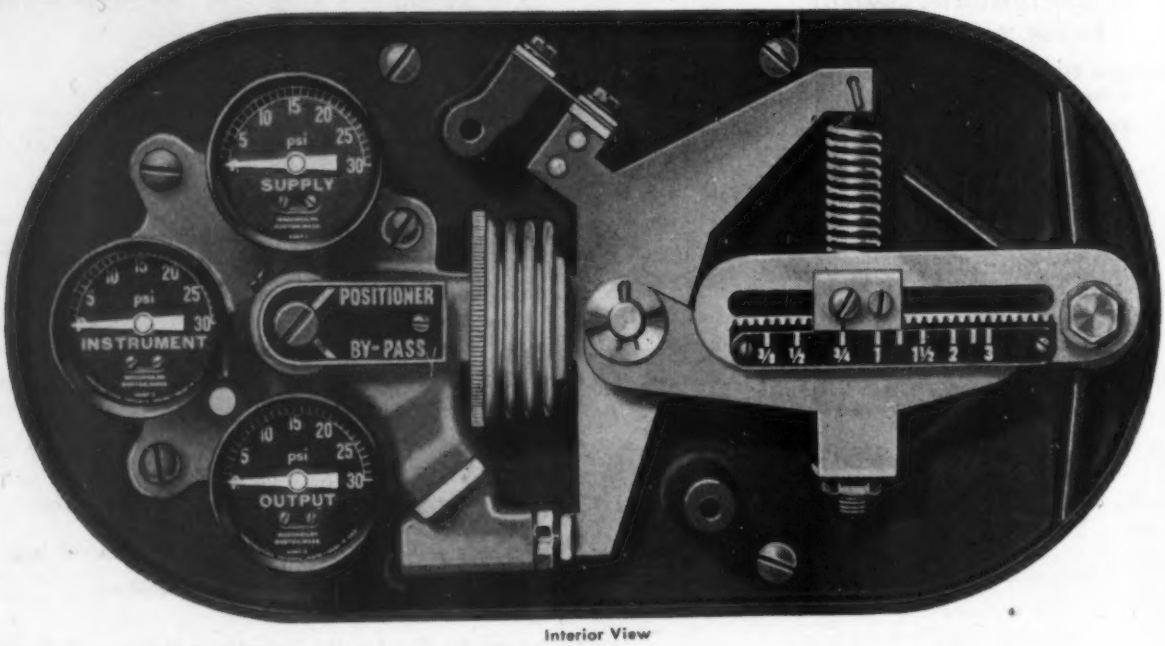

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THE LOOK BOX

A SIGNIFICANT innovation in industrial research circles is the action of Monsanto Chemical Company in establishing the new post of "Senior Industrial Scientist" for pioneer work in new fields and techniques, and the assignment of one of their foremost chemists, Albert H. Bump, assistant research director of the company's Merrimac division, to the task.

Forward Research Step

Dr. Charles Allen Thomas, executive vice president of the company, who conceived and instituted the post, outlined the new position and explained that the United States has too long relied on the basic inventions of Europeans, and that the nation must lead in original scientific research if it is to survive in an atomic age. The position of senior scientist was originated, he explained, to give outstanding scientists freedom for original research and to divorce their work from more limited industrial activity. In a recent address, Dr. Thomas ascribed the atomic bomb to "the restless European imagination." "The bomb was made possible because Chadwick, an Englishman, discovered the neutron; Hahn and Meitner, Germans, had demonstrated uranium fission; and Enrico Fermi, an Italian, conceived the chain reacting pile." He added that among many important wartime and peacetime inventions by Europeans were the rocket bomb, the jet propelled plane and radar, as well as the wireless, the Diesel engine, plastics, buna rubber, viscose and acetate rayon, penicillin, novacaine, the X-ray, and television.

Physical destruction and moral disruption has brought about a serious decline in the field of science in European nations, Dr. Thomas said, and this country "can no longer look to other nations for the spark which America genius can blow, tender, and fan into a great fire." The originality and creativeness of American research must be stimulated to new heights if the gap created by the European decline is to be bridged.

WHAT the adherents of control fail to comprehend is that regulations all too often are responsible for waste. An instance at hand is the effort to amend the federal statute under which the Federal Power Commission operates. There is a growl of complaint in the press, some of it based on the proposition that any change will result in freedom of operation in the movement of natural gas.

Control or Conservation

Unless there is a change in the statute, producers of natural gas simply are not going to sell their product to any company for interstate movement for the simple reason that this gives the commission authority to shove its control back down the line until it classes the producer of gas as a part of public utility operation, which in turn means that 6 percent is the maximum money return from operating that property.

All of that may sound good to the editorial writer, whose audience consists of gas users. But the thousands who produce gas are citizens along with those who burn gas. The matter of having no property capable of giving a return higher than 6 percent is of vital concern out in the oil and gas fields. Unless there is a change in the federal statute, producers of gas are going to sell only to

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those who move gas within state boundaries and that is going to result in waste, a practice not popular with the writers of editorials.

No such authority extends to other fuels and no such authority should be exercised over natural gas. Still the Congress adjourned without Senate action on the amendment. It is a piece of unfinished business of consequence.

Little Leeway

HOWEVER impressive 5,648,102 barrels of domestic refining capacity may seem as a set of figures, it falls short of comfort when measuring capacity against requirements for finished products. As any refinery worker knows, it is impossible to keep this combined national plant operating at 100 percent. Furthermore, the total includes plants of doubtful operating status, those off the beaten transportation trails and the few that get snarled in labor difficulties.

The total is from the report of the committee on refining of the National Petroleum Council, which noted that in the first two weks of June the plants of the United States operated at 91 percent of this total capacity. This is a high rate of operation, which to quote from the report of the committee, "leaves little flexibility or factor of safety."

Since the report was filed there has been improvement in the labor situation and 50,000 barrels of capacity shortly will be back on stream.

But the industry needs the extra capacity that is involved in the outstanding construction program of the industry. New and more efficient plants and units are the comforting solution.

Not the Answer

IT WAS a normal reaction to hear the tirade against shipments of oil to Russia as a solution to the shortages of supply at home. It so happens, however, that exports (those to Russia included) are not equal to our imports.

Lack of sufficient gasoline at the service station pumps in these United States gets back to the simple fact that its consumption has grown more rapidly than facilities can be completed to manufacture this commodity. Day after day the refining plants of the United States are processing more than 5,000,000 barrels of oil. By recent comparison that is a material jump in the use of any product and something even the most optimistic prognosticators did not anticipate.

The solution lies in getting more steel fabricated into processing equipment. Thus far there has been no shortage of crude oil, although the high output in excess of 5,000,000 barrels daily is near proper operating rates for the oil fields of the nation.

What to do about exports to Russia, therefore, becomes a political problem instead of simply an economic problem. It does seem that the nation whose reserves are estimated to be greater than those of the United States is in a peculiar position when it comes to these shores for its petroleum supplies. Either the Russian technology is no match for its natural resources or the political acumen of the United States is deficient.

In fairness to the corporations, which have been shipping to Russia, it should be pointed out that the total amount for this year has been at the rate of 1500 barrels daily. The shipments are made with full knowledge of the proper departments of the United States government, which have the responsibility to decide whether the shipments represent good or bad policy.

We Need To Know

THE shortcoming of the legislative investigation is that it reveals results rather than causes. Just now there is inquiry into the shortage of petroleum products in the Middle West. Customers know that the shortage (the result) exists, because they can get only limited supply at each purchase. Little can be gained by revealing what is already evident.

What caused or what will relieve the shortage is more vital and the Congress is not disposed to do much about that.

What the industry and the public need is more facilities for making gasoline. And that can be stimulated more quickly and more satisfactorily through investment than by any other means. If the Congress had the vision to make investment attractive by revision of tax laws, the whole manufacturing plant of the United States of which oil is but a small part, would grow up to meet demand.

The object should be to put dollars to work profitably. When dollars go to work, men go to work and customers get all they want of what they want at the fairest price level, one fixed by competition.

Hot Seat

FAILURE of the Department of Justice to answer questions asked almost a year ago has prompted Sun Oil Company again to seek information concerning charges specifically against it in the "Mother Hubbard" anti-trust suit, which has been pending for seven years. The latest thrust at the department points out that the questions of last July were filed "in an attempt to learn what part of an alleged conspiracy Sun Oil Company is charged with playing." Further in its latest move the company recites that:

"The department has charged against 366 defendants a variety of offenses, which if committed by any of them, cannot in the nature of things have been committed by them all."

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Refinery Planning

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In the author's comments, it is stated that this paper reviews recent technological developments in petroleum refining to provide a background for prediction of future trends. It is believed than any major revamping or expansion of refinery operations which does not provide the means of producing premium and regular gasolines having motor method octane ratings of 85 and 80, respectively, does not satisfactorily answer the refiner's problem. In addition to meeting these specifications, however, the following factors should also be considered in planning for the future:

1) **Importance of research octane as an indication of road performance,**
2) **Increased demand for distillate fuels,**
3) **Importance of long range viewpoint in selection of new processes,**
4) **Economies which can be effected in present operations without major processing changes.**

Data are presented to illustrate the effect of catalytic cracking on refinery planning through the production of gasoline of high octane number and the conversion of heavy stocks to distillate fuel. It is pointed out that a part of the cost of major processing changes can often be borne by the savings resulting from economies in present operations.

THE importance of sound planning for the expansion of refining facilities to meet the rising demand for high quality petroleum products can not be overemphasized. This is especially true for the smaller refiner who is faced with the problem of modernizing equipment which is now earning reasonable returns on the original investment, but will not satisfy future market demands for higher octane number. Frequently there is a tendency to overlook certain factors and adopt a somewhat short range point of view which may satisfactorily solve an immediate problem at low capital cost, but fails to provide a sound basis for future operations. The purpose of this paper is to review briefly the wartime developments in petroleum refining which are now widely used to produce improved motor fuels and to discuss several factors which should be considered in future planning. In discussing these developments it is of interest to review first the situation in refineries before the war.

Situation in Refineries in 1939

The average smaller refinery in 1939 contained topping, thermal cracking and, in some cases, thermal reforming and polymerization facilities. Polymerization was the first of the catalytic processes used to produce motor fuel and approximately fifty of these units were placed in operation duing 1939. Both catalytic cracking and hydroforming were in large scale commercial operation at that time. The catalytic alkylation of paraffin hydrocarbons with olefins for the production of aviation gasoline was also in commercial use. The catalytic dehydrogenation of butanes to butylenes had passed the pilot plant stage of development and three commercial units were under construction. The butylenes were to be catalytically polymerized into iso-octanes and catalytically hydrogenated to iso-octanes.

All of these catalytic processes produced gasoline of much higher quality than that obtainable with conventional thermal equipment but, with the exception of polymerization, all were too costly to be used by the smaller refiner. These factors did not greatly affect the refiner's position at that time, however, because thermal cracking and polymerization could usually be easily justified on the basis of increased gasoline yield from crude and reduced tetraethyl lead costs. Average motor method octane numbers of premium and regular grade gasolines were approximately 78 and 71,[7] respectively.

Developments During 1939-1945

Numerous papers[3, 5, 6] have been published recently describing the important technological developments in petroleum refining during the war and the trends which may be expected in the future. Hence, only a brief review of these developments is needed for the purposes of this paper.

The most oustanding change in refining processes was, of course, the tremendous increase in the use of the catalytic cracking process. The total rated capacity of catalytic cracking plants in 1945 was about 1,000,000 barrels per day,[2] or approximately 40 percent of the capacity of thermal units.[1]

Catalytic polymerization units which had been designed primarily to produce motor gasoline were operated at lower than normal temperature during the war on butane-butylene fractions to produce codimer which was hydrogenated to produce a saturated product of 92 octane number for use in aviation fuels. This was one of the few ways in which a smaller refiner could contribute directly to the manufacture of 100-octane aviation gasoline. At the end of hostilities, most of these units returned to operation on C_3-C_4 fractions at higher temperatures and greater throughputs to produce polymer gasoline.

The alkylate produced by alkylating isobutane with propylene, butylene or amylene was one of the principal components of 100 octane aviation gasoline. Isomerization processes for producing isobutane from normal butane were extensively installed and overcame the principal bottleneck in alkylate production by increasing the available quantity of the key raw material. The production of cumene by alkylating benzene with propylene accounted for about 23 percent of the increased production of 100-octane aviation fuel up to the end of 1943. Shortly thereafter aviation gasoline production was greatly increased

TABLE 1

Comparison of Sensitivities of Gasolines Produced from Mid-Continent Crude by Various Processes

GASOLINE	270° F., E.P. Light Straight Run	270-406° F., Straight Run Naphtha	Thermally Cracked	Isoformed Thermally Cracked	Mild Thermally Reformed Straight Run Naphtha	Fluid Catalytically Cracked
Gravity °API	71	50	58	57	54	59
Reid Vapor Pressure	12	1	4	4	4	5
End Point, °F.	270	400	400	400	400	400
Octane Ratings:						
Motor Method Clear	61	38	67	69	62	81
Motor Method + 3.0 cc. tel/gallon	81	61	76	79	76	86
Research Method + 3.0 cc. tel/gallon	81	61	85	87	82	98
Sensitivity (Research-Motor) with 3.0 cc. tel/gallon	..	..	9	8	6	12

by the new catalytic cracking and alkylation units placed in operation.

The dehydrogenation of butanes was employed in several refineries during the war to produce butylene for alkylation or butadiene for the manufacture of rubber.

Hydroforming, which was a prewar development, was found to be the most practical method of producing toluene for explosives, and its use was greatly increased.

Of all these catalytic processes which were used so extensively during the war, only catalytic cracking and polymerization appear to be economical for motor fuel manufacture in smaller refineries in the United States today.

Situation Today

Since the war and the relaxing of government controls, there has been a tremendous emphasis on the construction of new catalytic cracking and polymerization units. Since V-J day approximately 430,000-barrels-per-day of new fluid catalytic cracking unit capacity (U. S. and foreign) has been built, or is now in the design or construction stages. The effect this increased capacity will have upon the octane number picture is naturally viewed with some apprehension by the smaller refiner who operates thermal cracking equipment. Some refiners are in a more fortunate octane number position than others in that they are processing crude which contains straight run gasoline of higher than average quality, and the amount of upgrading required to compete with catalytically cracked gasoline motor method octane numbers may not be too excessive. Others with straight-run gasoline of average quality may normally market a large part of the heavy naphtha as tractor distillate or solvents, and thus eliminate this low octane material from the high grade gasoline blends. In such cases, thermal reforming, iso-forming or catalytic desulfurization are possible methods of reaching the required motor method octane level with relatively low investment cost. A number of smaller refiners, however, may now find it necessary to consider expanding or replacing existing cracking facilities by the installation of catalytic cracking in order to meet their anticipated octane requirements.

Refining in the Future

Past trends in the octane rating of motor gasoline have indicated[7] that by 1950 premium and regular gasolines may have motor method octane ratings as high as 85 and 80 respectively. It is thought, therefore, that any change in refinery processing which does not provide the means of producing gasoline of this quality does not satisfactorily answer the refiner's problems. In addition to meeting these specifications, however, there are several other factors which should be included in planning for the future. These factors can be listed as follows: 1) Importance of research method octane as an indication of road performance; 2) Increased demand for distillate fuels; 3) Importance of long range viewpoint in selection of new processes; and 4) Economies which can be effected in present operations without major processing changes.

Research Method Octane

The sensitivity (research method octane number minus motor method rating) of motor fuels is assuming increased importance. Some authorities[4] believe that the research method is a better indication of road performance, particularly under conditions of low speed knocking, than the motor method. Trends[7] have indicated that research method octanes of 95 and 88, corresponding to 85 motor method premium and 80 motor method housebrand, may be required by 1950.

As an indication of the improvemnt in research method octane and sensitivity to be expected by the installation of various processes in the average Mid-continent refinery, the properties of various gasolines produced from low sulfur Mid-continent crude are compared in Table 1. Note that the cracked and reformed gasolines are compared on a debutanized basis while the light straight run gasoline has a Reid vapor pressure of 12 pounds. In this comparison both the research method octane and the sensitivity of gasoline produced by fluid catalytic cracking, even at the intermediate reactor temperature of 875° F. at which the test was made, are somewhat higher than that produced by any of the other processes listed. It can be readily seen, therefore, that a refiner choosing such relatively low cost processes as thermal reforming or isoforming as a temporary means of reaching higher motor method octane number will probably be low on research octane number without catalytic cracking.

Distillate Fuels

The trend toward greater demand for intermediate distillates will have a significant effect on the refiner's planning for new facilities. Last year the demand for diesel fuel, furnace oil and light gasoil increased approximately 5 percent over 1945[2] and this trend is expected to continue. Data have been presented in the literature to show the great increase in distillate fuel yields which can be obtained when fluid catalytic cracking instead of thermal cracking is employed in a given refining scheme. This is due to at least one inherent difference between the two cracking processes. Thermal cracking is

TABLE 2

Fluid Catalytic Cracking 23° API Heavy California Gasoil Commercial Results

YIELDS	Volume Percent of Charge
(Dry gas, 382 cubic feet per barrel, charge)	.....
Propane-propylene cut	4.4
Butane-butylene cut	7.1
Light gasoline	17.2
Heavy gasoline	16.5
Light cycle oil	23.2
Heavy cycle oil	27.5

PROPERTIES OF CHARGE AND PRODUCTS

Properties	Charge Stock	Light Gasoline	Heavy Gasoline	Light Cycle Oil	Heavy Cycle Oil
Gravity, °API	23.0	67.3	38.9	23.3	19.4
Aniline point, °F	160	.....	.....	100	150
Percent Sulfur	0.80	0.07	0.19	0.70	0.60
Flash point, °F	260	.....	.....	240	220
Conradson Carbon, Wt., percent	0.12	.....	.....	0.03	0.94
Octane Numbers:					
Motor method clear	.....	79.2	79.6	.....	.....
Research method clear	.....	94.7	93.3	.....	.....
100 ml. Distillation:					
I. B. P. °F	390	107	269	451	.....
10 percent	600	128	286	492	.....
50 percent	740	162	327	542	.....
90 percent	860	220	389	622	.....
End Point, °F	.....	259	438	679	.....

always accompanied by thermal polymerization which makes heavy residuum at the high pressures employed, whereas fluid catalytic cracking is a low pressure process in which the catalyst modifies the cracking reaction so that little polymerization takes place. The catalytic cracking process will therefore increase the flexibility of refinery operations over that now realized with thermal cracking due to its greater ability to vary the proportions of gasoline and distillate fuels produced to meet seasonal demands for these products.

Recent data obtained on a commercial fluid catalytic cracking unit while processing a 23° API-gravity heavy California vacuum gasoil are shown in Table 2. The unit was operated at a conversion of approximately 50 percent in order to produce relatively low boiling distillate fuel as well as high octane motor gasoline from the vacuum gasoil. Note that the light catalytic cycle stock produced represents 23.2 percent of the charge and has a 50 percent point of 542° F. as compared with a 50 percent point of 740° F. on the fresh feed. It is also interesting to note that the light and heavy gasolines produced in this operation at a reactor temperature of 950° F. have sensitivities of 14 to 16 unleaded.

Importance of Long Range Viewpoint in Selection of New Processes

In a refinery containing crude distillation, thermal cracking and polymerization facilities, a number of interim steps can be taken to improve over-all gasoline quality. As previously mentioned, the straight-run gasoline can be reformed or desulfurized and the cracked gasoline can be isoformed to increase octane rating. It is apparent from process studies that catalytic cracking will ultimately be required to meet anticipated product specification, however, the need for installing a new reforming, desulfurization, or isoforming process must be carefully analyzed.

One of the most important factors to be considered in this analysis is, of course, the ratio of the amount of low octane straight run gasoline which must be up-graded to the amount of available catalytic cracking stock. It is often found that the quantity and blending value of the catalytically cracked gasoline are sufficient to carry all of the available low octane number straight run naphtha in blends even when producing 85-octane premium and 80-octane house-brand gasoline. In borderline cases only a moderate increase in the octane rating of the straight-run naphtha will be required to make the 85-80 grades after the future installation of catalytic cracking. This increase can usually be obtained by thermally reforming the heavy naphtha at mild conditions.

In the past, thermal reforming units have normally been operated to increase octane rating at conditions which result in gasoline yields of about 80 percent. Because of the accompanying rather high loss of gasoline production, some refiners have tended to discredit a consideration of this process in future planning. It should be remembered, however, that the thermal reforming operation shows a greater incremental increase in octane rating per unit loss in gasoline yield at lower conversion levels. This effect is illustrated in Figure 1 which shows the yield octane number relationship obtained by thermally reforming a 34 octane number Mid-continent straight-run naphtha. The heavy straight-run naphtha is usually the lowest octane number material used in motor fuel blends in the average Mid-continent refinery. It is interesting to note that this naphtha can be thermally reformed to a motor method octane number of 49 clear and 68 with 3cc tel gal., at a yield of 95 percent, on a debutanized basis. While this operation in itself does not produce any 85 octane gasoline, it is quite effective in improving the octane number of the total refinery gasoline blends with little loss in total gasoline production. For example, a refiner processing 38° API Mid-continent crude and producing light straight-run gasoline, heavy naphtha, thermally cracked gasoline and polymer could increase the motor method octane number of the total gasoline blend 2-3 points by this procedure. The corresponding research method octane rating could be increased 3-4 points.

Pilot plant tests indicate that the catalytic reforming of low sulfur heavy Mid-continent naphtha over

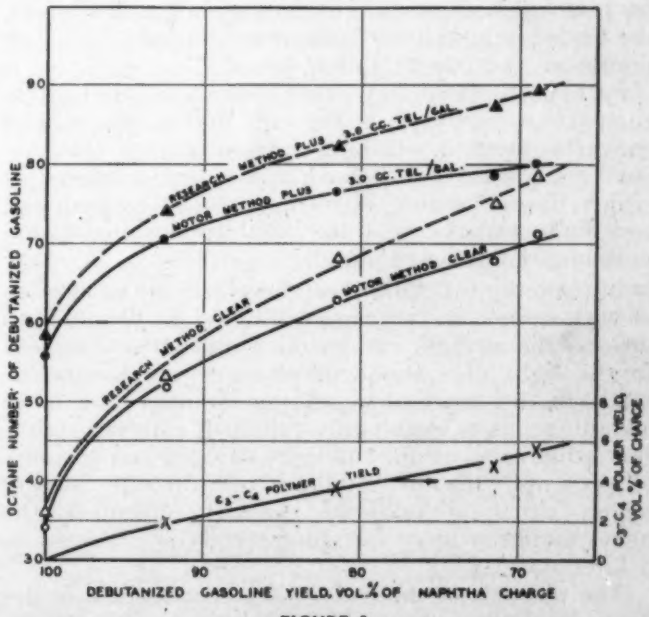

FIGURE 1

Thermally reforming Kansas straight run naphtha, 34 octane, 250-400° F. boiling range, 0.03 percent sulphur.

the fixed bed clay type catalyst would show little or no advantage over mild thermal reforming from the standpoint of yield octane relationship, and it would have the disadvantage of being limited to operation at low conversion level unless sufficient regeneration capacity were built into the unit to handle the high coke production at high conversion. The less expensive thermal reforming operation, on the other hand, can be conducted at conversions corresponding to gasoline yields of 75 to 80 percent if the additional octane improvement is required and sufficient heater capacity is available. When considering the installation of a new reforming unit, the available reforming capacity both before and after conversion of the thermal cracking unit to catalytic cracking should be taken into consideration. From the long range viewpoint it would obviously not be feasible to install new thermal or catalytic reforming capacity which could not be justified when catalytic cracking is required.

When high sulfur crudes are processed the possibility of desulfurizing the full boiling straight run gasoline over a fixed bed of hot clay to improve octane number and lead susceptibility suggests itself. The economics of this operation should be compared, however, with that of thermally reforming only the heavy straight run naphtha at mild conditions. The amount of desulfurization and the increase in lead susceptibility obtained by this reforming operation are often overlooked in future planning. Table 3 shows the results of a pilot plant test on a 48 octane number West Texas naphtha containing 0.27 percent total sulfur. A yield of 94.4 percent of gasoline having a clear motor method octane rating of 64.5 after doctor sweetening was obtained at the mild operating conditions employed. The gases produced can be polymerized to yield an additional 2.3 percent of polymer gasoline based on the charge if refinery butanes are available for vapor pressure. It is significant to note that this operation resulted in about 55 percent desulfurization of the naphtha with an increase of 16 points in the leaded octane rating at the 3.0 cc/gallon level. While catalytic desulfurization of this naphtha would effect a slightly greater sulfur removal with essentially no loss in gasoline yield, the leaded octane improvement would only be 6 to 8 points at the 3.0 cc/gallon level.

Perhaps a more important consideration in this comparison, however, is the fact that a refiner who converts thermal cracking equipment to catalytic cracking probably will have equipment available in which this reforming operation can be carried out, and the installation of a new catalytic desulfurization unit might not be required.

In planning for the future, therefore, the economics of various new installations which might be added to process the straight run gasoline must be considered in the light of subsequent changes which may be made in the processing scheme. It might be more advantageous to install only sufficient catalytic desulfurization capacity for the light straight run gasoline at present, with the intention of utilizing existing heater capacity for mild thermal reforming the heavy naphtha after installing catalytic cracking at a later date.

The position of the isoforming process in a future refinery scheme employing catalytic cracking must also be analyzed. If catalytic cracking is to replace thermal cracking eventually, the charge stock for the isoforming unit will be limited to reformed gasoline, which does not respond to this treatment as readily as thermally cracked gasoline. With a few modifications, this process could be converted to a catalytic reforming or desulfurization unit for the straight run gasoline. This would probably be the most advantageous use for this equipment although its operation would have to be justified in comparison with mild thermal reforming as previously discussed.

TABLE 3

Mild Thermal Reforming West Texas Naphtha

YIELDS	
Naphtha charge	100.0
Reformed gasoline (9.4 lb. R.v.p.) Volume percent	94.4
Fractionator bottoms	2.1
Gas, cubic feet per barrel of charge	164

OPERATING CONDITIONS	
Pressure, psig	500
Transfer temperature, °F	960

Properties of Products	Charge	Reformed Gasoline	Fractionator Bottoms
Gravity, °API	49.9	52.7	29.0
Total Sulfur, Weight, Percent	0.27	0.12	.....
Mercaptan Sulfur, Weight, Percent	0.08	0.04	.....
Reid Vapor Pressure, Pounds	.....	8.5	.....
Octane Number, Motor Method*:			
Clear	47.5	64.5	.....
Plus 1.0 cc. tel/gal.	51.5	70.5	.....
Plus 3.0 cc. tel/gal.	59.5	75.5	.....
100 ml. Distillation:			
I. B. P., °F	191	108	396
10 percent	259	199	412
50 percent	311	293	450
90 percent	374	367	630
End Point, °F	408	399	709

* After doctor sweetening.

Economies Which Can Be Effected In Present Operations

Of increasing importance in recent years is the necessity for strict economy of refinery operations. With increased cost of crude, labor and raw material, many refiners are carefully re-examining over-all costs to determine what economies can be effected by simple changes in operating procedure. Experience has shown that the margin of refining can be increased appreciably in many cases by properly applying engineering knowledge to increase operating efficiency. When considering new installations to meet higher octane specifications, therefore, it is advantageous to investigate the over-all refining scheme including auxiliary equipment such as tankage, boiler house and treating facilities. Frequently it is found that economies brought about by revamping or modifying some auxiliary step can offset an appreciable part of the total cost of new equipment.

TABLE 4

MOST COMMON METHODS OF EFFECTING ECONOMIES IN REFINERY OPERATIONS

(1) Reduce distillation, storage, and handling losses.
(2) Increase recovery of light hydrocarbons in cracking unit gas recovery system.
(3) Improve efficiencies of pumping, heating, and cooling.
(4) Reduce consumption of chemicals in treating.

Table 4 lists several of the most common methods by which economies can be effected in the average smaller refinery. Experience has shown that the crude distillation operation and the handling and

storage of products are often sources of considerable loss of revenue in over-all operations. In addition, most of these losses are due to the escape of light hydrocarbons which have the greatest value. The determination of the source of these losses requires an accurate daily log of inventory in sufficient detail to obtain weight balances over various sections of the refinery. Critical studies of several refineries have revealed that these losses, which may usually be recovered by simple methods, may amount to from 1 to 6 percent of the crude charge.

High crude distillation and rerunning losses are usually the result of undercutting the straight run gasoline to low endpoint in distillation units which are operated at atmospheric pressure. The necessity for increasing octane rating has led to a substantial reduction in endpoint of the light straight-run gasoline in most refineries and the gas losses from the distillation unit receivers have correspondingly increased. One method of reducing these losses is to preflash the crude under pressure and subsequently stabilize the light straight run gasoline. Other losses can be reduced by elimination of unnecessary handling of products by making the topping, rerunning and stabilizing operation continuous with less intermediate storage and pumping.

The increased demand for either LPG or olefinic gases for polymerization emphasizes the importance of revamping gas recovery units, which are often operated to recover only 50-60 percent of the olefins available for polymerization. The efficiency of recovery can frequently be improved by simple modifications of operations such as the use of improved absorption mediums and over-all improvement of absorption facilities. Extensive revamping of the gas concentration system is usually required, however, to obtain recoveries of the order of 75 percent of the propylene and 95 percent of the butanes-butylenes produced.

Thus far, the discussion of methods of effecting economies in refinery operation has been concerned principally with methods for reducing losses of valuable products. The last two methods listed in Table 4 have reference to reducing the so-called direct operating costs. In this connection it is of interest to examine a breakdown of total operating costs in an assumed average Mid-continent refinery. Table 5 shows these costs on the basis of processing 7000 barrels per stream day of low sulfur Mid-continent crude in distillation, thermal cracking, polymerization, and treating equipment. While the direct operating costs, excluding tetraethyl lead, amount to only 9 percent of the total cost of operation, it is significant to note that if this cost could be reduced to 7.5 percent of the total, the savings would be sufficient in the average case to amortize an investment of $1 million for new processes in ten years.

Steam and fuel costs are usually the most expensive items in the direct cost of operating the process units in an average Mid-continent refinery. In many cases fuel costs can be reduced by a) modifying or installing additional heat exchange surface, b) improving burner operation, and c) modifying the arrangement of baffles in the heaters. The installation of exhaust steam turbines has proved unusually successful in several refineries as a means of utilizing low pressure steam which is otherwise vented to the atmosphere. These turbines operate on steam at 2 to 5 pounds gauge pressure exhausting to a barometric condenser. The water rate usually amounts to 30-45 pounds/HP depending upon the size of the turbine.

TABLE 5

Breakdown of Costs in Refinery* Processing 7000 Barrels Per Stream Day of Low Sulfur Mid-Continent Crude

	Percent of Total Costs
Crude	72
Casinghead	8
Direct Operating (processing and treating)	9
Tetraethyl Lead	5
Indirect (Management, sales, overhead, depreciation)	6
Total (excluding income tax and interest)	100

* Topping, thermal cracking, polymerization, and treating.

While it is possible in many refineries to reduce treating costs by installation of more modern and efficient treating processes, there are often a number of steps in the existing treating procedure which can be modified to reduce cost. For example, modifications of the crude unit operation and stabilization of the straight-run gasoline as mentioned previously, will eliminate hydrogen sulfide from this stream and reduce the consumption of caustic in treating.

Summary

Recent developments in refining technology which now permit the petroleum industry to produce improved motor fuels have been briefly reviewed. The installation of the fluid catalytic cracking process has proceeded on a vastly increased scale since V-J day and its operation is being justified economically in comparison with thermal cracking on the basis of its ability to produce higher yields of gasoline and distillates at the expense of heavy fuel oil, with lower tetraethyl lead and treating costs.

Several of the more important factors which should be considered in future planning have been discussed. It has been pointed out that the selection of new processes for octane improvement should be considered from a long range viewpoint so that the minimum rearrangement of process equipment will be required if catalytic cracking is eventually installed. A stepwise approach to the problem of planning future additions and changes to the processing scheme is recommended.

While making major processing changes to improve octane rating a number of simple modifications in operating procedure can often be incorporated to reduce costs. Several examples of these methods of effecting economies in smaller refineries are mentioned. Detailed engineering and process studies will usually reveal other methods of improving the over-all refining scheme to provide a sound basis for future operations.

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Boiling Coefficients for Finned Tubes

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OVERALL coefficients of heat transfer have been measured for boiling isobutane and n-hexane outside of horizontal tubes. The removal of the steam condensate from the inside of the tube is shown to have a significant effect on the heat transfer. A finned tube having 2.4 times the outside surface of a plain tube gave from 1.4 to 2.0 times as much heat transfer per foot of length.

HEAT transfer coefficients from condensing steam inside a horizontal tube to a boiling liquid outside the tube have been reported for plain tubes.[7,2] Many investigators have shown the effect of temperature difference, nature of the surface, and pressure on boiling coefficients.[1,3,4,5,6] Data on the cooling of water inside of finned tubes by boiling refrigerant outside the tubes were reported for a unit containing 594 tubes.[8] This paper reports data on the boiling of hexane and isobutane outside an integral spiral finned tube with condensing steam inside the tube.

The rate of ebullition of vapor from the surface of heated metal immersed in a liquid depends upon the nature of the metal surface.[5,7,9,10] Although the shape of the surface has caused little effect on the boiling coefficients[4,6,7] no information has been reported as to the possible effects of fins on the outside of the tube on boiling, with the exception of the data on the water cooler.[8]

Steam condensing on the inside of tubes produces a liquid condensate which must be removed from the tube. The thickness of this condensate film controls the resistance to heat transfer and hence the characteristics of the apparatus which influence the removal of the condensate will affect the overall coefficient of heat transfer. The angle of tilt to cause condensate drainage and the steam velocity which sweeps the liquid along the tube were investigated in this research.

Apparatus and Procedure

Figure 1 and 1a are photographs of the apparatus and finned tube and Figure 2 is a diagrammatic flow sheet of the apparatus.[12] It consisted essentially of a continuous closed circuit still and condenser, each employing a single tube inserted through packing glands. The still had a 3" pipe for a shell with the tube set one-half inch below center. Windows were provided to observe boiling and the liquid level in the still. The still, condenser, and lines connecting them were covered with one inch of magnesia. Steam was supplied to tube in the still and cooling water to the condenser tube.

Four tubes were used in the still with dimensions given in Table 1. A plain copper tube and a finned copper tube each three feet long were employed. The other two tubes were three feet in length but were

TABLE 1
Dimensions of Tubes in Still

Tube Number	1A	2	3	4
Outside Diam., Inches	.748	.750	.748	.750
Inside Diam., Inches	.543	.651	.543	.651
Root Diam., Inches	.622	Plain	.622	Plain
Fins per Inch	14.48	Plain	14.48	Plain
Length, Feet	2.96	3.00	.647	.682
Outside Area, Sq. Ft.	1.45	.599	.317	.134

$$\frac{\text{Outside Area Tube No. 1A}}{\text{Outside Area Tube No. 2}} = 2.42$$

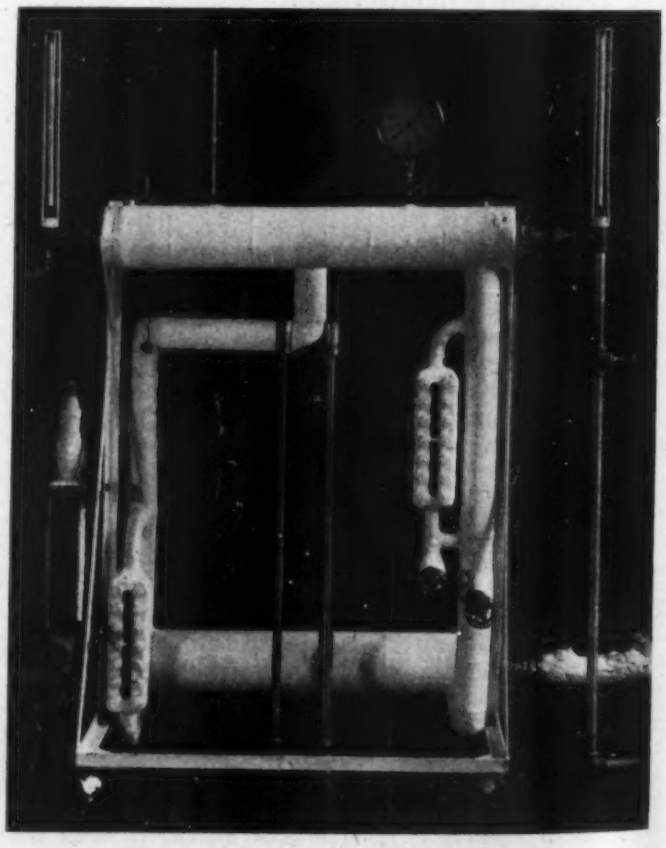

FIGURE 1
Heat Transfer Apparatus

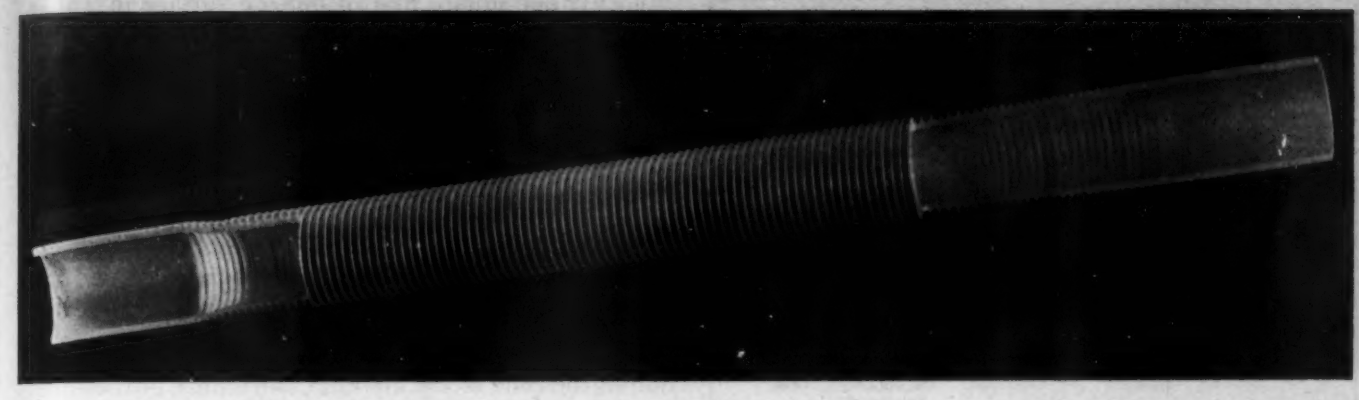

FIGURE 1-A
Finned Tube

Courtesy Wolvering Tube, Division.

insulated on the outside excepting for a central section about 6 inches long.

The temperature of the boiling liquid was obtained by a thermometer (T_3) inserted in a well below the surface of the liquid. The vapor temperature was observed by a thermometer (T_4) to insure that the

TABLE 2
Summary of Experimental Data

Run	Fluid	Tube	BOILING FLUID		Overall Temp. Difference	Heat Flux* B.t.u./Hr./ Ft.²†	Overall Coefficient B.t.u./Hr./°F./ Ft.²†	Tilt Inches in 3 Ft.	Steam Purge Lb./Hr.
			Temp. °F.	Pressure psia					
26	Hexane.....	1A	189.2	25	22.3	10,700	479	0.	Slight
27	Hexane.....	1A	189.0	25	22.4	11,070	494	.44	Slight
28	Hexane.....	1A	189.3	25	22.0	10,930	497	.81	Slight
29	Hexane.....	1A	190.2	25.5	21.1	10,840	514	1.50	Slight
30	Hexane.....	1A	190.3	25.5	21.0	10,930	521	2.00	Slight
42	Hexane.....	2	180.3	22.0	30.9	21,900	709	1.5	Slight
43	Hexane.....	2	164.7	17.0	46.4	30,800	663	1.5	Slight
44	Hexane.....	2	172.7	19.5	38.7	24,200	626	1.5	Slight
59	Isobutane...	2	176.0	206	34.1	42,900	1255	1.5	Slight
61	Isobutane...	2	158.0	167	52.9	62,600	1183	1.5	Slight
62	Isobutane...	2	190.5	240	20.7	26,700	1291	1.5	Slight
68	Isobutane...	1A	161.2	174	58.5	41,100	702	1.5	Slight
69	Isobutane...	1A	177.8	210	35.8	31,100	868	1.5	Slight
70	Isobutane...	1A	191.0	242	21.2	20,400	962	1.5	Slight
107	Isobutane...	1A	186.6	231	42.3	21,600	511	1.50	0
108	Isobutane...	1A	187.3	233	41.7	21,800	522	1.50	2.54
109	Isobutane...	1A	187.0	232	42.0	34,400	818	1.50	33.1
110	Isobutane...	1A	186.6	231	42.3	34,800	823	1.50	31.8
111	Isobutane...	1A	187.3	233	41.4	35,100	847	1.50	66.5
113	Isobutane...	1A	190.1	239	39.7	20,900	527	1.50	66.5
114	Isobutane...	1A	189.9	239	39.9	24,500	613	1.50	19.4
115	Isobutane...	1A	189.2	237	40.6	24,000	590	1.50	17.7
116	Isobutane...	1A	190.1	239	39.7	35,500	895	1.50	57.2
117	Isobutane...	1A	189.6	238	40.5	35,200	858	1.50	76.4
118	Isobutane...	1A	189.8	239	40.2	34,900	868	1.50	65.1
119	Isobutane...	1A	189.4	238	40.6	24,100	600	1.50	12.9
120	Isobutane...	1A	189.9	239	40.1	25,400	632	1.50	25.7
121	Isobutane...	1A	189.3	237	40.7	32,200	791	1.50	40.3
122	Isobutane...	1A	189.9	239	40.1	20,200	503	1.50	0
176	Isobutane...	4	105.1	86	105.5	116,100	1100	1.5	Slight
177	Isobutane...	4	104.0	85	154.5	94,600	612	1.5	Slight
178	Isobutane...	4	103.8	85	170.4	86,300	506	1.5	Slight
179	Isobutane...	4	104.7	86	182.4	76,500	419	1.5	Slight
180	Isobutane...	4	104.9	86	195.6	81,000	414	1.5	Slight
181	Isobutane...	4	140.5	136	70.1	108,000	1542	1.5	Slight
182	Isobutane...	4	140.0	135	119.9	132,000	1100	1.5	Slight
183	Isobutane...	4	141.1	137	132.1	143,900	1070	1.5	Slight
184	Isobutane...	4	140.4	136	146.6	130,000	890	1.5	Slight
185	Isobutane...	4	140.9	137	159.9	137,200	858	1.5	Slight
186	Isobutane...	4	194.2	250	108.7	122,500	1130	1.5	Slight
187	Isobutane...	4	194.3	250	90.1	111,000	1220	1.5	Slight
188	Isobutane...	4	194.5	251	79.1	93,300	1183	1.5	Slight
189	Isobutane...	4	194.4	251	63.3	77,800	1200	1.5	Slight
190	Isobutane...	4	193.5	249	17.1	25,300	1475	1.5	Slight
194	Isobutane...	4	194.5	251	44.7	60,000	1345	1.5	Slight
196	Isobutane...	4	140.2	136	100.7	133,800	1330	1.5	Slight
197	Isobutane...	4	140.5	136	86.1	115,800	1345	1.5	Slight
199	Isobutane...	3	103.8	85	106.8	66,200	620	1.5	Slight
200	Isobutane...	3	104.2	85	154.2	64,800	420	1.5	Slight
201	Isobutane...	3	104.2	85	170.5	62,700	368	1.5	Slight
202	Isobutane...	3	104.9	86	181.6	61,300	338	1.5	Slight
203	Isobutane...	3	104.7	86	198.3	59,000	298	1.5	Slight
204	Isobutane...	3	140.5	136	161.5	84,200	522	1.5	Slight
205	Isobutane...	3	140.0	135	146.6	85,500	583	1.5	Slight
206	Isobutane...	3	140.0	135	135.1	87,900	649	1.5	Slight
207	Isobutane...	3	140.4	136	117.0	85,600	733	1.5	Slight
208	Isobutane...	3	140.5	136	70.1	67,300	960	1.5	Slight
209	Isobutane...	3	192.4	246	18.2	21,000	1155	1.5	Slight
209A	Isobutane...	3	194.0	250	16.6	19,300	1163	1.5	Slight
212	Isobutane...	3	193.8	249	65.6	62,200	949	1.5	Slight
213	Isobutane...	3	195.3	253	102.7	87,400	851	1.5	Slight
213A	Isobutane...	3	195.1	252	102.4	88,700	866	1.5	Slight
214	Isobutane...	3	194.2	250	194.2	83,300	896	1.5	Slight
215	Isobutane...	3	193.5	249	80.9	78,600	971	1.5	Slight
217	Isobutane...	3	195.3	253	44.3	50,100	1132	1.5	Slight
220	Isobutane...	3	140.7	136	86.3	81,800	947	1.5	Slight
220A	Isobutane...	3	140.4	136	87.0	79,900	919	1.5	Slight
221	Isobutane...	3	140.6	136	97.2	80,800	832	1.5	Slight
222	Isobutane...	3	104.5	85	132.5	62,700	469	1.5	Slight

* Heat flux computed from heat absorbed by cooling water in condenser plus a radiation loss of 2000 B.t.u./Hr. at 194° F., or 1900 B.t.u./Hr. at 140° F.

† Coefficients and heat flux are based on outside areas for the tubes.

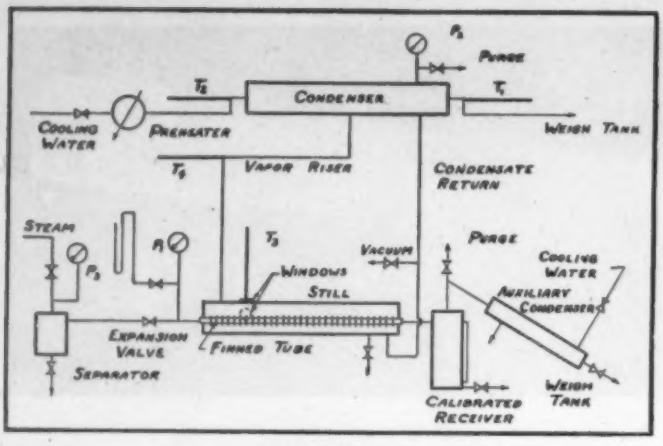

FIGURE 2
Flow Diagram

vapor was saturated at the boiling temperature. The pressure measurement in the condenser served as a check on the boiling temperature. The water rate in the condenser was observed by weighing and the temperature difference was obtained by thermometers graduated to 0.1° F. The steam pressure was observed by a mercury manometer and a pressure gauge. Steam condensate was collected in a calibrated receiver.

The still and condenser were evacuated before charging with isobutane or hexane. The liquid level used in still without boiling was about ¾ inch above the tube. Steam was admitted to the tube in the still at a predetermined pressure and the pressure on the boiling liquid was maintained at a fixed value by control of the condenser water flow. After the temperatures reached a steady state, data were observed while collecting a weighed quantity of cooling water, with average readings reported as a "run." Whenever a large discrepancy occurred between the heat transfer in the condenser and that in the still, the data were discarded.

Experimental Results

The variables used in the series of tests besides the fluids and tubes were the pressure on the boiling liquid, angle of tilt of the apparatus, and the rate of steam removal from the condensate receiver. The essential data are reported in Table 2.

The experimental data are reported as overall coefficients per square foot of outside surface in Table 2. Three separate conductances are represented by the overall coefficient; the boiling coefficient, the metal conductivity, and the condensing steam coefficient. In order to obtain boiling coefficients, the condensing steam coefficient and the metal conductivity must be known. The resistance (reciprocal of coefficient) of the boiling liquid is equal to the overall resistances of the condensing film and the metal resistance.

The removal of the steam condensate from the inside walls of the tube would decrease the resistance of the condensing steam and hence increase the overall coefficient of heat transfer. The angle of inclination of the tube to a horizontal, the length of the tube, the rate of heat transfer and the velocity of the steam passing through the tube are variables which would influence the rate of condensate accumulation in the tube and hence affect the overall resistance.

Figure 3 presents the effect of tilting the apparatus when boiling hexane with a 3-foot finned tube No. 1 A. The observed increase in heat transfer with tilting is relatively small, but definite. The effect of the angle of inclination of the tube would be more pronounced for longer tubes and at higher rates of heat transfer.

Figure 4 presents the effect of steam velocity on the overall coefficient. The increases in steam velocity were accomplished by bleeding steam from the condensate receiver through the auxiliary condenser. The steam velocity is a composite value for the steam condensing in the still tube as well as of the steam passing through the tube of the auxiliary condenser. The increase of the overall coefficient from 520 to 890 by the sweeping action of the steam on the condensate film is significant.

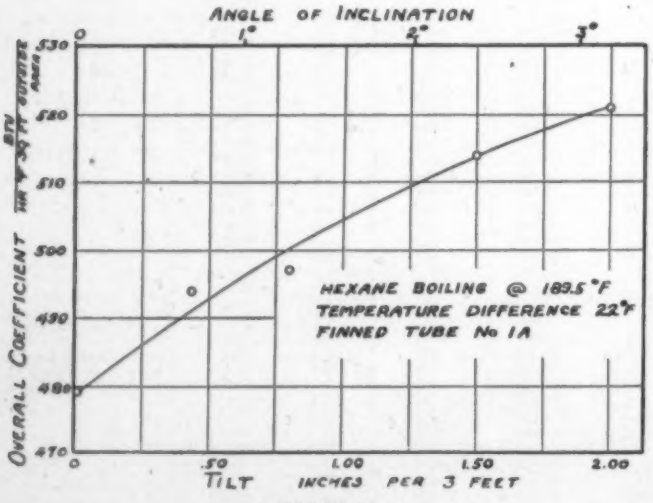

FIGURE 3
Effect of Tilting on Boiling Coefficient

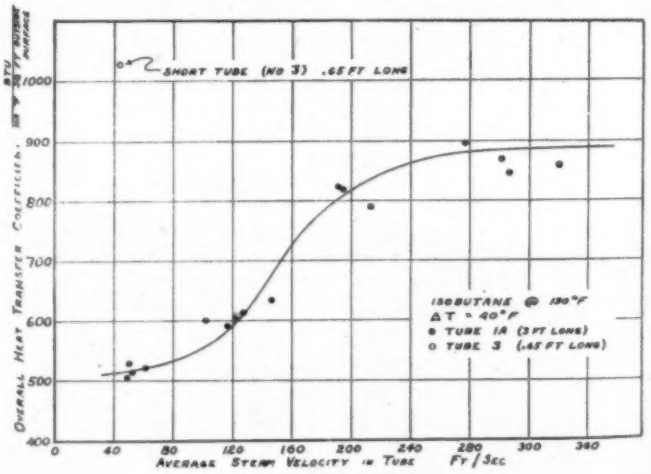

FIGURE 4
Effect of Steam Velocity on Boiling Coefficient

Effect of Metal Resistance

The effect of the length of the tube is also shown on Figure 4. The overall coefficient for the short length (0.65 ft.) of tube demonstrates that a small accumulation of condensate, either by a short length or by high steam velocities given similar rates of heat transfer. In commercial still coils the steam velocity cannot be controlled for the last portion of the steam to be condensed.

The copper wall has a low resistance to heat transfer and a negligible temperature drop occurs between the inside of the tube and the root of the fin. Some temperature drop between the root and tip of the fin

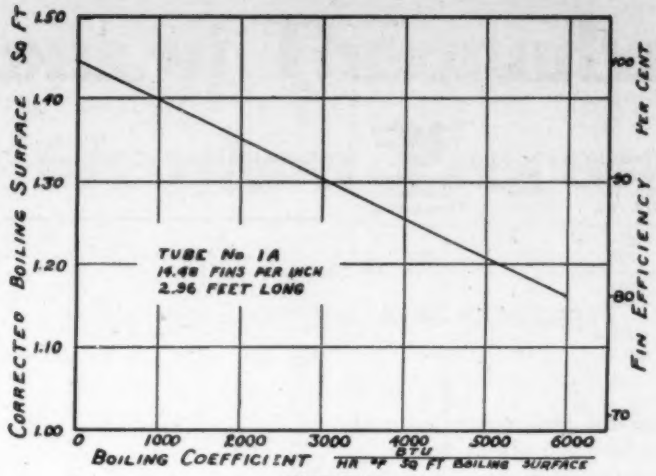
CORRECTED BOILING SURFACE Sq Ft
FIN EFFICIENCY PER CENT
TUBE No 1A
19.48 FINS PER INCH
2.96 FEET LONG
BOILING COEFFICIENT BTU / HR °F Sq Ft BOILING SURFACE

FIGURE 5

Effect of Fin Efficiency (Copper Tube)

will occur, with temperature difference increasing with rates of heat transfer. Gardner[11] has presented a method of predicting a fin efficiency to account for this temperature drop. Figure 5 shows the effective outside area of the finned tube as a function of the boiling coefficient.

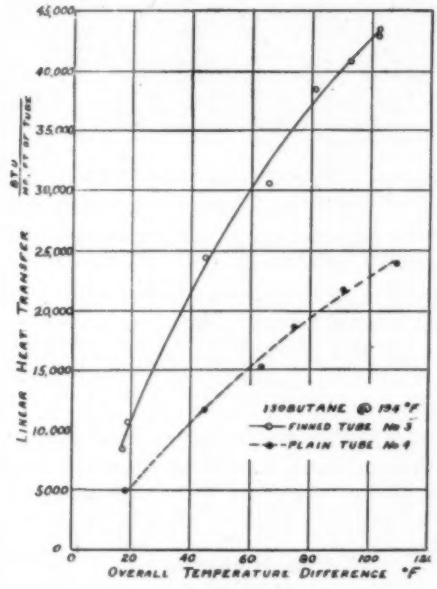

FIGURE 6

Comparison of Finned and Plain Tubes per Unit Length

From the standpoint of performance, the heat transfer per foot of tube makes a good comparison of finned and plain tubes. Figure 6 shows the heat transfer per foot of tube versus temperature difference.

Figure 7 is a plot of the overall coefficients versus temperature difference. The decrease in coefficients indicates that film boiling occurs with increased tem-

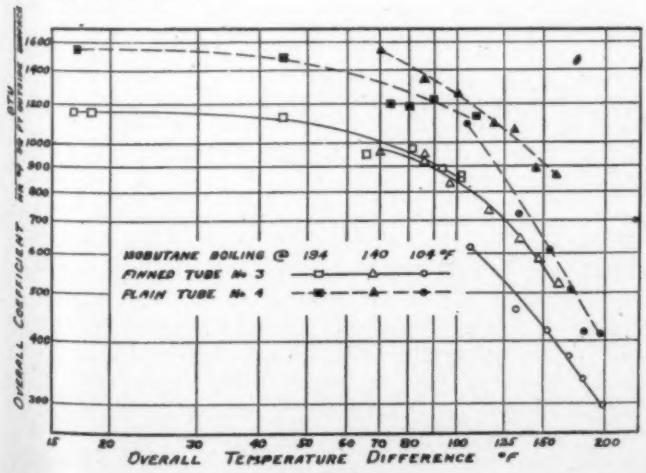
OVERALL COEFFICIENT BTU / HR, SQ FT OUTSIDE SURFACE
OVERALL TEMPERATURE DIFFERENCE °F
ISOBUTANE BOILING @ 194 140 104 °F
FINNED TUBE No 3
PLAIN TUBE No 4

FIGURE 7

Overall Coefficient for Boiling Isobutane on Short Tubes

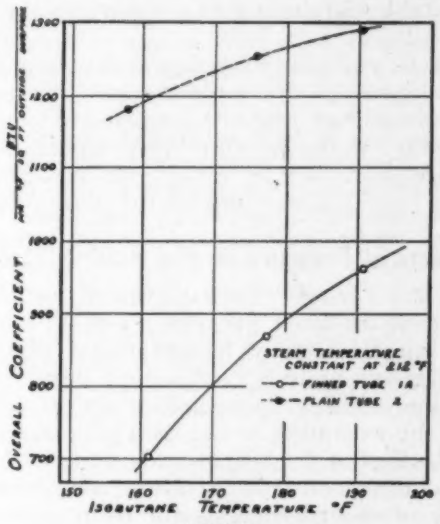
OVERALL COEFFICIENT BTU / HR, SQ FT OUTSIDE SURFACE
ISOBUTANE TEMPERATURE °F
STEAM TEMPERATURE CONSTANT AT 212 °F
FINNED TUBE 1A
PLAIN TUBE 2

FIGURE 8

Comparison of Finned and Plain Tubes per Unit Outside Surface

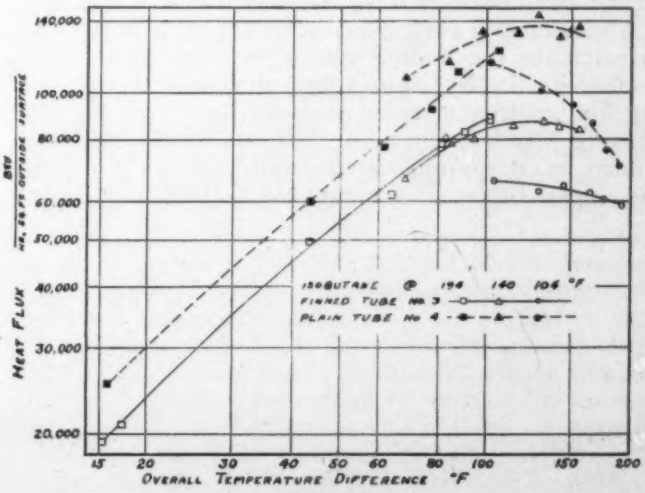
HEAT FLUX BTU / HR, SQ FT OUTSIDE SURFACE
OVERALL TEMPERATURE DIFFERENCE °F
ISOBUTANE @ 194 140 104 °F
FINNED TUBE No 3
PLAIN TUBE No 4

FIGURE 9

Heat Flux in Boiling

TABLE 3

Over-all Coefficients for Boiling Isobutane Outside 3-Foot Tubes

Run	Isobutane Temperature °F.	Overall Temperature Difference, °F.	Overall Coefficient B.t.u./Ft.²/ /°F./Hr.	Tube No.	Ratio of Heat Transfer per Degree Temperature Difference Finned: Plain
62	190.4	20.7	1291	2	
70	191.0	21.2	962	1A	1.80
59	176.0	34.1	1255	2	
69	177.4	35.8	868	1A	1.68
61	158.0	52.9	1183	2	
68	161.2	58.5	702	1A	1.44

perature difference while boiling isobutane around the short tubes. The finned tube gave about twice as much heat transfer per foot as the plain tube for this case with tube sections 0.65 ft. long. Table 3 presents a comparison between the heat transfer for the 3-foot tubes boiling isobutane with the ratios of the heat transfer per foot per °F. from 1.79 down to 1.43. Figure 8 is a plot of the overall coefficients, showing a more rapid increase of heat transfer coefficient for the finned tube with increased pressure on the boiling fluid.

Figure 9 is a plot of heat flux versus temperature difference showing the temperature differences at which the maximum rate of heat transfer is attained. There appears to be no significant variation in the temperature difference at which the maximum heat flux occurs for the finned and for the plain tube.

Effects of Pressure on the Boiling Fluid

Bonilla and Cichelli[4] have reported the effects of pressure (and reduced pressure) on boiling coefficients on an electrically heated metal plate. They found increased boiling coefficients with increased pressure, increased temperature or decreased viscosity. With the exception of the data on the plain tube at 194° F., Figure 7 confirms this general trend by boiling isobutane outside of tubes. Also, the higher magnitude of the coefficients for isobutane as compared to hexane are in agreement with the relationship reported.

Boiling Coefficients

Prediction of the boiling coefficient from overall coefficients is practically impossible from the data obtained. Figure 4 indicates that the boiling coefficient is well over 1000 for the conditions of that test. If a condensing coefficient is assumed, it is possible to calculate the boiling coefficient from the overall coefficient. Table 4 shows the calculation of the boiling film coefficient from assumed values of the condensing steam coefficient. The fin efficiency is included in computing the resistance of the metal for the finned tubes. The computed boiling coefficients

TABLE 4

Calculated Boiling Coefficients

Overall Coefficient from Figure 7, B.t.u./Hr./ /°F./Sq. Ft.*	Over-all Temperature Difference °F.	Assumed Steam Film Coefficient B.t.u./Hr./ /°F./Sq. Ft.†	Fin Efficiency Percent	Calculated Boiling Coefficient B.t.u./Hr./ /°F./Sq. Ft.*
PLAIN TUBE				
1550	20	4000	....	2960
1490	40	4000	....	2750
1320	70	4000	....	2220
1210	90	4000	....	1930
1550	20	8000	....	2080
1490	40	8000	....	1970
1320	70	8000	....	1685
1210	90	8000	....	1508
1550	20	15000	....	1820
1490	40	15000	....	1740
1390	70	15000	....	1537
1210	90	15000	....	1390
FINNED TUBE				
915	90	4000	75.8	7290
1160	20	8000	90.1	2920
1130	40	8000	90.8	2740
1010	70	8000	92.9	2120
915	90	8000	94.2	1740
1160	20	15000	93.8	1240
1130	49	15000	94.1	1760
1010	70	15000	95.1	1480
915	90	15000	95.6	1290

* Outside effective surface. † Inside condensing surface.

are in the range from 1200 to 3000 Btu/hr. °F. square feet. Actually the low temperature differences will have a higher condensing coefficient than the higher temperature differences.

The boiling coefficients for the finned tube per square foot of effective finned surface are somewhat lower than for the plain tube, the heat flux per foot of tube is over twice as much for the finned tube as for the plain tube.

The above data on single tubes may give lower coefficients than a bank of tubes for low temperature differences since the agitation caused by boiling increases the heat transfer of all but the bottom tubes in the bank.

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Applications of Thermodynamics to Hydrocarbon Processing

Part II

BASIC DEFINITIONS AND CONCEPTS

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THERMODYNAMICS is a natural science which deals with energy and the transformation of energy and with equilibrium and the equilibrium distribution of products. For many years thermodynamics has been a very useful tool in the design and operation of steam boilers, engines and turbines, of internal-combustion engines, of refrigeration units, and of heating and ventilating equipment. Until recent years, however, very few efforts had been made to apply thermodynamics to chemical and chemical engineering problems which are encountered in the processing of petroleum. There are two reasons why the development of this branch of thermodynamics lagged in the development of the so-called *"Engineering Thermodynamics,"* namely: (1) mechanical engineering problems were more pressing due to the harnessing of the recently invented steam engine, turbines, and internal combustion engine; and, (2) chemical and chemical engineering thermodynamics is complicated by varying composition of the working fluid, hydrocarbon mixtures and petroleum fractions offering some very troubling problems. Progress in the solution of these problems has been rapid during recent years so that new equipment can now be designed without too much "thermo" guessing. Many thermodynamics applications are necessary to keep process design technique apace with the development of new petroleum refining processes.

The first article of this series presented a summary of the fundamentals and applications of thermodynamics. This, the second article of this series, will be devoted exclusively to the basic definitions and concepts of thermodynamics that are prerequisite to the development of charts and equations for the application of thermodynamics. Before taking up the basic laws of thermodynamics and the relations developed from them, various terms and concepts will be defined and attention given to the concise methods of mathematics that will be used.

A "homogeneous" system is one whose properties are the same in all parts of the system, or at least vary continuously from point to point; a system in which there are no apparent surfaces of discontinuity. A "heterogeneous" system consists of two or more distinct homogeneous regions. These homogeneous regions, which may be different "phases" (gaseous, liquid or solid) of the same substance, or a mixture of two or more immiscible substances, appear to be separated from one another by surfaces of discontinuity. Systems may be further classified according to whether they contain one or more pure substances. Any system that contains more than one pure substance is a "solution" or a "mixture."

The "state" or "phase" condition of a system depends on its properties. Properties that are dependent on the mass of the substance under consideration are known as "extensive" properties. Properties that are not dependent on the mass of the substance are called "intensive" properties.

Attention will be given to the following intensive and extensive properties in these articles:

Intensive Properties

T = Temperature
P = Pressure
f = fugacity
$\gamma = C_p/C_v$ = specific heat ratio
$\mu = \left(\frac{\delta T}{\delta P}\right)_H$ = Joule-Thomson coefficient

Extensive Properties

V = Volume
C_p = Specific heat at constant pressure
C_v = Specific heat at constant volume
S = Entropy
A = Residual work (Helmboltz Free Energy)
F = Free Energy (Gibbs Free Energy)
E = Internal Energy
H = Enthalpy

"Equilibrium" is a state of rest. A system that is not at equilibrium is moving in that direction. Although equilibrium conditions can be estimated by thermodynamics, the rate at which equilibrium is approached cannot be predicted by thermodynamics alone. The approach to equilibrium involves the study of kinetics and the use of data on reaction rates, diffusivities, etc. Most hydrocarbon processes are steady-flow processes. Equilibrium in such processes is a "dynamic" rather than a "static" state. The definition of equilibrium as a state of "rest" cannot be taken literally. In a flow process a state of "rest" (equilibrium) means "no tendency to change," which may apply to temperature, pressure, phase conditions, etc.

Mathematics

Mathematics has been defined as a shorthand for the precise formulation of well standardized ideas. In this respect, mathematics is the language of thermodynamics. In addition to arithmetic and algebra, differential and integral calculus are used extensively in the development and applications of thermodynamic relationships. Graphical as well as analytical methods of differentiation and integration are applied in this work. The amount of calculus really essential in thermodynamics is very small and this mostly is used in developing charts and tables of derived thermodynamic properties. Arithmetic and algebra are usually sufficient in applying these tables and charts to processing calculations. However, an intimate familiarity with this small amount of essential calculus is nec-

essary to a thorough understanding and a workable knowledge of thermodynamics.

All thermodynamic properties that will be treated in later discussions depend on two or more variables. In many thermodynamic equations there are more variables than are required to define the function. Those variables which are required are called the "independent" variables while the remaining are called the "dependent" variables, the dependent variables being dependent on the independent variables. From a mathematical standpoint, any two (or more as the case may be) of the variables may be arbitrarily chosen as the independent variables, leaving the remaining variables as the dependent variables. Most frequently it will be convenient to call pressure and temperature P and T, the independent variables.

For single-component systems (pure compounds) P and T are the only independent variables necessary. Theoretically, all the above extensive properties and all the remaining intensive properties may be defined as functions of these two independent variables. In practice, it does not always work out this way, however. For example, a correlation of volume as an explicit function of pressure and temperature would be most convenient from a thermodynamic standpoint but it is not possible to express such a correlation accurately in analytical form. However, it is possible to express pressure as an accurate function of volume and temperature. Although such a correlation can be made accurately, it is not explicit in volume, which is a drawback. Consequently, many thermodynamic equations use other properties, such as the volume or the entropy as the independent variables. In some cases such variables can be replaced by pressure and temperature in the final correlations so that ultimately P and T are the only independent variables.

For multi-component systems it is necessary to include enough additional variables to define the composition of the mixture. The percentage of one component is sufficient for a two-component system, the percentage of two components for a three-component system, etc. It is obvious that this problem can get very complicated for a multicomponent system unless the mixture is defined in terms of average molecular weights, boiling points and/or gravities for the mixture rather than in terms of components.

Since the thermodynamic properties to be treated depend on two or more variables, it is necessary to use repeatedly the methods of partial differentiation. If V depends on the two variables, P and T the differential change in the dependent variable V, resulting from a differential change in either of the independent variables, the other being constant, may be expressed by the following partial differential equations:

$$dV = \left(\frac{\delta V}{\delta T}\right)_P dT, \text{ and } dV = \left(\frac{\delta V}{\delta P}\right)_T dP$$

the subscript indicating which independent variable is being kept constant. The total differential of V resulting from infinitesimal changes in both temperature and pressure will be

$$dV = \left(\frac{\delta V}{\delta T}\right)_P dT + \left(\frac{\delta V}{\delta P}\right)_T dP \qquad (1)$$

The addition of another variable such as the percentage of one component in the system results in the following more general equation:

$$dV = \left(\frac{\delta V}{\delta T}\right)_{P,N} dT + \left(\frac{\delta V}{\delta P}\right)_{T,N} dP + \left(\frac{\delta V}{\delta N}\right)_{P,T} dN \qquad (2)$$

The equation is only a statement that the whole is made up of all its parts and represents the general equation of partial differentiation, which is the most useful tool in dealing with changes in the properties of a system.

There are special forms of equation 1 which are very useful in making thermodynamic formulations. If V is constant as it would be along a contour line of the P-V-T surface, $dV = 0$ and

$$\left(\frac{\delta V}{\delta T}\right)_P dT + \left(\frac{\delta V}{\delta P}\right)_T dP = 0$$

Dividing through by dT and expressing the constancy of V in the equation gives the following useful relation:

$$\left(\frac{\delta V}{\delta T}\right)_P + \left(\frac{\delta V}{\delta P}\right)_T \left(\frac{\delta P}{\delta T}\right)_V = 0 \qquad (3)$$

For some other dependent variable, that is, some other quantity which, like the volume, depends only upon the temperature and pressure, such as the entropy S, each member of equation 1 may be divided by dT and the condition of constant S imposed to obtain the following useful relation:

$$\left(\frac{\delta V}{\delta T}\right)_S = \left(\frac{\delta V}{\delta T}\right)_P + \left(\frac{\delta V}{\delta P}\right)_T \left(\frac{\delta P}{\delta T}\right)_S \qquad (4)$$

This equation states that the change in V corresponding to a given infinitesimal change in T (i.e. moving along a constant entropy contour upon the P-V-T surface) is the sum of two terms; namely; the change in V, which would be caused by this change in T alone, and the change in V caused by such a change in P as is necessary to keep S constant. Equations 3 and 4 are useful in transforming variables

There are six useful transformations of variables that are applied in developing thermodynamic formulations. The first three involve three variables, which will be called P, V, and T. The last three involve four variables, which will be called, P, V, T, and S. In all of six of these transformations the expression $(\delta V/\delta T)_P$ is changed to something else. The variables and starting expression are arbitrary. The resulting transformations may be applied to any other combination of variables and starting expression. These six transformations, which were presented in the first article of this series as Table 1, are derived by manipulating differential equations defining the relationships of the variables in the manner demonstrated above. It is not necessary to go through all the details as all the final transformation equations are given in Table 1. These transformations are very helpful in developing thermodynamic formulations as will be apparent later.

After the thermodynamic formulations are set up the next steps are to evaluate the derivatives and integrate the resulting expression. In case second derivatives are involved, the following relation may be used to simplify the problem:

$$\frac{\delta}{\delta P}\left(\frac{\delta V}{\delta T}\right)_P = \frac{\delta^2 V}{\delta P \delta T} = \frac{\delta}{\delta T}\left(\frac{\delta V}{\delta P}\right)_T \qquad (5)$$

Derivatives may be evaluated analytically or graphically. Analytical differentiation is often complicated by the fact that it is not always possible to obtain an expression that is explicit in the dependent variable, thus making the use of implicit differentiation necessary. Graphical methods of differentiation are frequently the best solution to this problem. The "chord area method" is one of the best methods of graphical differentiation. In finding $(\delta V/\delta T)_P$ by this method the following procedure is used: (1) from isobaric plots of V vs. T find $\Delta V/\Delta T$ for each pressure, taking

temperature intervals small enough to get sufficient accuracy and yet not so small that slight unsmoothnesses in the data or plots of the data are reflected in the derivatives; (2) plot these values of $\Delta V/\Delta T$ as chords versus T; (3) through these chords draw a smooth curve (one for each pressure) so that the areas between the chord and the curve are equal, i.e., area above chord equal area below; and (4) the resulting curve is a plot of $(\delta V/\delta T)_P$ versus T, the values of the derivative being read from the same scale used in plotting the chords.

Similar graphical methods may be used in integrating. The procedure to be followed in graphically integrating an expression in which P and T are the independent variables is as follows: (1) choose a reference state; i.e., pressure and temperature; (2) evaluate the coefficient of dT at the reference pressure and then plot against T; (3) integrate the temperature function by counting squares or with a planimeter, and evaluate the integration constant so that the result has a value of zero at the reference temperature; (4) evaluate the coefficient of dP at various temperatures and plot against pressure; (5) integrate the pressure function to the pressure used in the temperature integration; and (6) evaluate the final integral by combining the results of the temperature and pressure integrations.

When plotting large values of one variable which differ little from each other, the precision may be increased by plotting on an enlarged scale the portion of the plot on which the point lies or for which derivatives are desired. This method is not very satisfactory, however, because a number of large graphs are required. A more accurate and satisfactory method is to use a residual quantity, which is defined as the difference between the actual curve and an approximate yet easily formulated curve for the same data. For example, the residual volume is the differential between the ideal gas volume and the actual gas volume. The residual gas volume has been found very convenient in differentiating and integrating P-V-T data. This subject will be discussed further in a later article.

Conservation of Energy—First Law

In steady-flow systems, such as most hydrocarbon processes, three types of energy are involved, namely: "potential energy," "kinetic energy," and "internal energy." Until relatively recent times the first two kinds of energy, which are exemplified by the elevated body and the moving body, respectively, were all that was required in scientific work. Potential and kinetic energies form the basis for mechanics, in which their sum is known as "mechanical energy." As science progressed, it became necessary to invent other forms of energy, such as "electrical energy" and "internal energy," the latter being very important in the study of thermodynamics.

The manner in which the "potential energy" of a body or system of bodies may be converted to "kinetic energy," or vice versa, by reason of the relative positions and velocities of component parts of the system is a well established principle of mechanics. If an energy transfer of this kind takes place in a system where frictional processes are at work, there will be a net loss of mechanical energy so that the sum of the potential and kinetic energies will diminish. This decrease in mechanical energy is not actually lost. It is transformed to heat, the amount of heat produced being equal to the amount of mechanical energy lost. The discovery of this phenomena in the 18th century led to the consideration of heat as a form of energy, and to the enunciation of the broad principle which we know as the law of the "conservation of energy" or the "first law of thermodynamics." In other words, the first law of thermodynamics states that heat and mechanical work are interchangeable (one Btu is equivalent to 777.5 foot-pounds, etc.).

The law of the "conservation of energy" is used in developing Bernoulli's theorem for fluid flow. It should be understood that the first law of thermodynamics implies more than a mere statement that energy is a quantity that is constant in amount. Energy may be likened to an indestructible and uncreatable fluid which cannot enter a given system except from or through surrounding systems. It would not satisfy the conservation law if one system were to lose energy, and another system, at a distance, were to gain energy in the same amount simultaneously. The immediate surroundings must lose or gain energy, the energy flowing into or out of the system through its boundaries.

Internal energy is an extensive property of a system and changes in it are independent of the way the change is brought about. An increase or decrease in "internal energy" is simply the difference between the final and initial energies regardless of the path followed in making the change. Internal energy of a substance consists of the kinetic energy of the particles (molecules, atoms, etc.), of the electrical energy emanated by the charged particles, and of other forms of energy not yet named. In the study of thermodynamics no cognizance is taken of all these forms of energy that make up the total internal energy of a system. The absolute value of the internal energy is of no interest either, as changes in total internal energy are sufficient.

Work Functions

The work done on a fluid or done by a fluid is a function of the path followed on the PV coordinates,

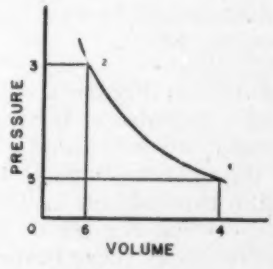


FIGURE 1
P-V diagram for deriving work relationship.

see Figure 1. From this diagram, the following relations are obvious:

$$\text{Area } 1235 = \int_{P_1}^{P_2} VdP = \text{Flow or shaft work on fluid}$$

$$\text{Area } 2306 = P_2V_2$$

$$\text{Area } 1264 = \int_{V_1}^{V_2} PdV = \text{Batch or self work by fluid}$$

$$\text{Area } 1405 = P_1V_1$$

The area 1235 is called the "flow" or "shaft" work. This work function applies to a flow process. As the integral is written, it expresses the work done on a fluid in compressing it from point 1 to point 2. Changing the sign or integrating from point 2 to point 1 gives the work done by the fluid upon expanding from point 2 to point 1.

The areas 2306 to 1405, expressed as P_2 V_2 and

P_1V_1, are known as the "pressure" energies at points 2 and 1, respectively.

The area 1264 is known as the "non-flow" or "self" work. This work function applies to a batch process. As the integral is written, it expresses the work done by the fluid in expanding from point 2 to point 1. Changing the sign or integrating from point 1 to point 2 gives the work done on the fluid in compressing the fluid from point 1 to point 2.

By considering the geometrical relationship of the areas shown in Figure 1, a relation is found between these work functions. An addition of areas gives:

Area 1235 = Area 1264 + Area 2306 — Area 1405

Combining with the above expressions for each area gives the following relations:

$$\int_{P_1}^{P_2} VdP = \int_{V_2}^{V_1} PdV - (P_1V_1 - P_2V_2) \qquad (6)$$

Equation 6 states: "The flow or shaft work done on a fluid in compressing it from point 1 to point 2 equals the batch or self work done by the fluid in expanding from point 2 to point 1 minus the change in pressure energy." The pressure energy term may be replaced by its equivalent $\Delta(PV)$. Making this substitution and changing signs gives the following expression which will be useful in a later derivation

$$-\int_{P_1}^{P_2} VdP = +\int_{V_1}^{V_2} PdV - \Delta(PV) \qquad (6)$$

To avoid confusion the flow work may be designated by W_F and the batch work by W_B. For a batch process the total work $W = W_B$. For a flow process the total work $W = W_F$.

Energy Functions

According to the first law of thermodynamics, (conservation of energy), any system in a given condition contains a definite quantity of energy, and when this system undergoes change, any gain or loss in its internal energy is equal to the loss or gain in the energy of surrounding systems. In any ideal batch or non-flow process (physical or chemical), the increase in energy of a given system is equal to the "heat absorbed" by the system from its surroundings minus the "work done" by the system upon its surroundings. If E_1 represents the initial energy content and E_2 the final energy content, then:

$$E_2 - E_1 = \Delta E = Q - W_B \qquad (7)$$

For the path shown on Figure 1, W_B is negative in going from point 1 to point 2. If heat is given up by the system instead of absorbed and if work is done on rather than by the system, both Q and W will have the opposite signs in equation 7. The change in the internal energy between the points 1 and 2 depends only on the conditions at these points (i.e., pressure, volume and temperature) and not at all on the path followed between these points. The work done and the heat absorbed, on the other hand, depend on the path followed as well as on the initial and final conditions.

When a system loses energy by radiation, convection, conduction or friction, it is giving up "heat." When it loses energy by other methods, such as operating against external mechanical forces, it is doing "work." If a non-flow or batch system is subject to a constant external pressure and is allowed to expand against that pressure so that its increase in volume is ΔV, then the work done by the system is:

$$W_B = P\Delta V$$

or, if the external pressure varies during the process:

$$W_B = \int_{V_1}^{V_2} PdV$$

The sign will be determined by the values of V_1 and V_2. If $V_1 > V_2$, as in Figure 1, W_B from this equation is negative. If this expansion is carried out in such a manner that no heat enters or leaves the system, the process is said to be adiabatic and:

$$-\Delta E = W_B = \int_{V_1}^{V_2} PdV \qquad (8)$$

If, on the other hand, the process is such that no work is done upon the surroundings (as in the case of a reaction taking place as a batch process at constant volume), then:

$$\Delta E = Q \qquad (9)$$

First Law Derivations

The concept of energy as set forth by the first law of thermodynamics permits defining several useful functions and partially formulating these functions (it is not possible to complete these equations at this stage because of limitations in the first law), thus preparing the way for the concept of entropy, which is necessary to complete the derivations of the various thermodynamic functions. The enthalpy, heat capacity and Joule-Thomson effect will be taken up next.

Enthalpy. Most petroleum operations are not batch processes but are steady-flow processes where the pressure and not the volume are kept constant. In a steady-flow process, the internal energy, E, is not as significant or as useful as the sum of the internal energy and the pressure energy, PV. This sum has been defined as the "enthalpy," H, where:

$$H = E + PV \qquad (10)$$

Being the sum of the two point functions E and PV, the enthalpy is also a point function and changes in it depend only on the initial and final conditions and not at all upon the path followed. In other words:

$$H_2 - H_1 = \Delta H = (E_2 + P_2V_2) - (E_1 + P_1V_1)$$

or

$$\Delta H = \Delta E + \Delta(PV) \qquad (11)$$

Combining equations 7 and 11:

$$\Delta H = Q - W_B + \Delta(PV) \qquad (12)$$

$$\Delta H = Q - \int_{V_1}^{V_2} PdV + \Delta(PV) \qquad (13)$$

The last two terms of equation 13 may be replaced by a single expression, equation 6, which was derived above.

Combining equation 6 and 13:

$$\Delta H = Q - \int_2^1 VdP = Q + \int_1^2 VdP \qquad (14)$$

When pressure is constant:

$$\Delta H = Q \qquad (15)$$

Equation 15 is analogous to equation 9.

Heat Capacity. The average "heat capacity" between the initial and final states is defined as $Q/\Delta T$, and the limit of this ratio as Q is made indefinitely small, or, in other words, as the two temperatures are brought near each other, is the actual heat capacity at that point. The amount of heat required to produce a given rise in temperature will, however, depend upon the circumstances under which the system is heated. Consideration will be given to the addition of heat at constant volume and at constant pressure.

When heat is added at constant volume there is no work and the heat absorbed is equal to the increase in internal energy (see equation 9). Therefore:

$$C_V = \left(\frac{\delta E}{\delta T}\right)_V \qquad (16)$$

When heat is added at constant pressure, on the other hand, the heat absorbed is equal to the increase

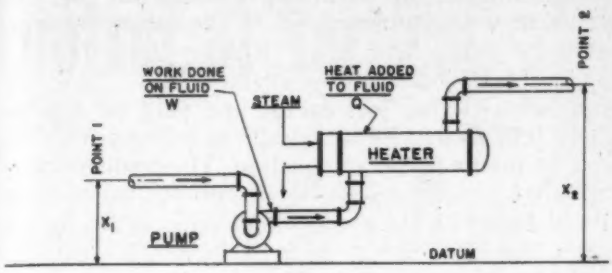


FIGURE 2A
Work done on fluid and heat added to fluid.

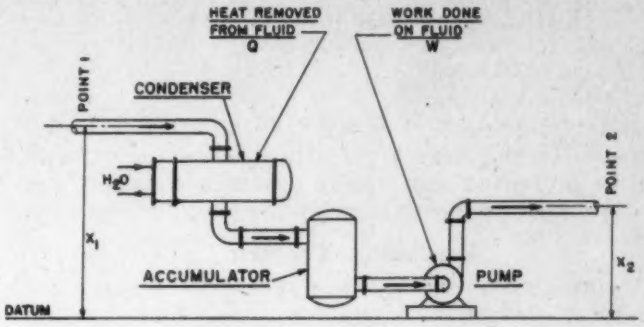


FIGURE 2B
Heat removed from fluid and work done by fluid.

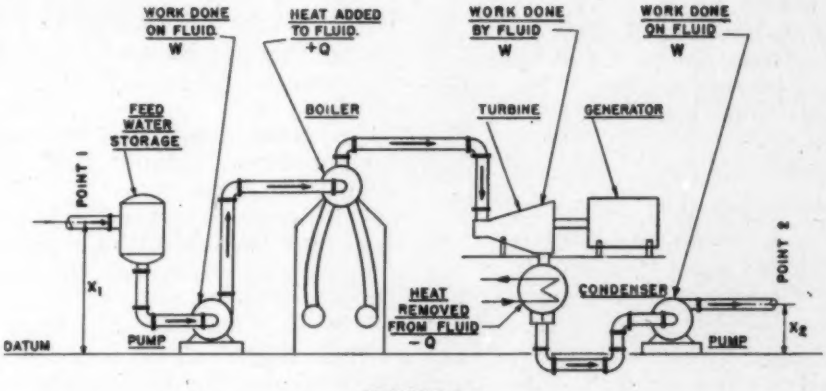


FIGURE 2C
Work and heat added to fluid, work done by fluid and heat removed from fluid.

EXAMPLE OF STEADY FLOW APPARATUS, ILLUSTRATING TOTAL ENERGY BALANCE

in the enthalpy, as shown by equation 15. Therefore:

$$C_P = \left(\frac{\delta H}{\delta T}\right)_P \qquad (17)$$

An equation for the difference in specific heats at constant pressure and volume may be derived from these definitions of specific heats and equation 11 relating the enthalpy and the internal energy by using the sixth transformation of variables (see Table 1 of Part I of this series). Dividing equation 11 by ΔT and expressing constancy of V results in the following:

$$\left(\frac{\delta H}{\delta T}\right)_V = \left(\frac{\delta E}{\delta T}\right)_V + V\left(\frac{\delta P}{\delta T}\right)_V \qquad (18)$$

Writing the sixth transformation in terms of the variables P, V, T, H gives:

$$\left(\frac{\delta H}{\delta T}\right)_V = \left(\frac{\delta H}{\delta T}\right)_P + \left(\frac{\delta H}{\delta P}\right)_T \left(\frac{\delta P}{\delta T}\right)_V \qquad (19)$$

Combining equations 16, 17, 18 and 19, gives the following equation for the difference in specific heats:

$$C_P - C_V = \left[V - \left(\frac{\delta H}{\delta P}\right)_T \right] \left(\frac{\delta P}{\delta T}\right)_V \qquad (20)$$

An analogous equation may be derived from equation 11 by starting off with constancy of P and proceeding in this same manner, which results in the following equation:

$$C_P - C_V = \left[P + \left(\frac{\delta E}{\delta V}\right)_T \right] \left(\frac{\delta V}{\delta T}\right)_P \qquad (21)$$

These equations for the difference in specific heats have been carried as far as possible without the use of entropy. By means of the second law, the development of these equations may be completed. Both equations 20 and 21 yield the same final equation for C_p-C_v. No energy or enthalpy terms appear in this final equation.

Joule-Thomson Effect. At ordinary temperatures and pressures, all gases and vapors, except hydrogen and helium, show a cooling effect when allowed to expand freely from a higher pressure to a lower pressure with no addition or removal of heat. Hydrogen and helium show a heating effect. The production of liquid air depends solely upon this phenomenon, which is known as the Joule-Thomson effect, being named for the two men who first performed the experiment in an English brewery early in the 19th century. In this classic experiment, the gas was allowed to expand slowly through a porous plug and it was found that the temperature dropped, but no heat was removed so $Q = 0$ in equation 12, giving:

$$\Delta H = \Delta(PV) - W_B \qquad (22)$$

Since the pressures on each side of the plug or expansion valve are maintained constant, the net work done by the system is $W_B = P_2V_2 - P_1V_1$, which makes equation 22,

$$\Delta H = (P_2V_2 - P_1V_1) - (P_2V_2 - P_1V_1) = 0 \qquad (22A)$$

Therefore, the process is one of constant enthalpy and the Joule-Thomson coefficient is defined by the equation:

$$\mu = \left(\frac{\delta T}{\delta P}\right)_H \qquad (23)$$

By using the third transformation the following equa-

tion for the Joule-Thomson coefficient is obtained

$$\mu = \left(\frac{\delta T}{\delta P}\right)_H = -\frac{\left(\frac{\delta H}{\delta P}\right)_T}{\left(\frac{\delta H}{\delta T}\right)_P} = -\frac{1}{C_P}\left(\frac{\delta H}{\delta P}\right)_T \quad (24)$$

$$\mu C_P = -\left(\frac{\delta H}{\delta P}\right)_T \quad (25)$$

This is as far as it is possible to go without using entropy. In the next article the concept of entropy will be presented and a more practical equation will be developed by means of relations based on entropy.

Bernoulli's Theorem

A corollary of the first law of thermodynamics is the total energy balance on a steady-flow system, from which useful equations are derived. This energy balance and the resulting equations are known as Bernoulli's Theorem. The basic Bernoulli equation is derived by considering the steady flow in the apparatus shown in Figures 2A, 2B and 2C and making a total energy balance in mechanical (foot-pounds) energy units, using as a basis, one pound of fluid entering at point 1 and also leaving at point 2. The various types of energies and their values are:

Potential Energy = X
Kinetic Energy = $U^2/2g$

Pressure Energy = force x distance = $P \times A \times \frac{V}{A} = PV$

Internal Energy (thermal, chemical, and otherwise) = E
Work Done to the Fluid = W_F
Heat Added to the Fluid = Q

The internal energy, E, is a fundamental property of the fluid.

Conservation of energy requires equality of the sum of all forms of energy entering to those leaving, resulting in the following total energy balance:

$$X_1 + \frac{U_1^2}{2g} + P_1V_1 + E_1 + W_F + Q = X_2 + \frac{U_2^2}{2g} + P_2V_2 + E_2 \quad (26)$$

Based only on laws of conservation of matter and energy, this equation is fundamental and its validity is beyond question. Bernoulli's Theorem is derived from this total energy balance.

Both E and PV are properties of the fluid and their sum has been defined as the enthalpy (see equation 10). In terms of H, the above total energy balance equation becomes:

$$\frac{U_1^2 - U_2^2}{2g} + (X_1 - X_2) + Q + W_F = (H_2 - H_1) \quad (27)$$

If changes in potential and kinetic energies can be neglected, equation 27 becomes $Q + W = \Delta H$, which is equation 14. At constant pressure, $W_F = 0$ and $Q = \Delta H$.

The above total energy balance equations have many applications. Two useful forms of the energy equation are developed below.

Nozzle Flow. For flow through adiabatic orifices, jets and nozzles, the initial velocity is usually negligible in comparison with the final velocity. In addition no heat or work is supplied from the outside so both Q and W equal zero. For these conditions equation 27 becomes:

$$U_2 = 223.7\sqrt{H_1 - H_2} \quad (28)$$

where U_2 = final velocity in feet per second
H_1 = initial enthalpy, Btu/lb.
H_2 = final enthalpy, Btu/lb.

For the ideal frictionless adiabatic (reversible) case, H_1 and H_2 are at the same entropy, i.e., reversible adiabatic (entropy and irreversibility will be discussed in Part III). In actual practice, however, there will be an increase in entropy so that the final temperature will be higher and the final velocity lower than for the ideal frictionless case. If the initial and final temperatures are known the actual final velocity may be found by the above equation. If not, it may be approximated by assuming a value for "w," the friction or wire-drawing loss, in the following equation:

$$U_2 = 223.7\sqrt{(1 - w)(H_1 - H_2)} \quad (29)$$

where w = friction loss factor and may be approximately 0.10 to 0.2. Equations 28 and 29 are modified forms of the total energy equation. These equations are frequently applied to steam in turbine calculations.

Fluid Flow. As far as petroleum processing is concerned, the most useful form of Bernoulli's equation contains a friction energy term, but does not contain Q, E, or H. This equation is derived by rewriting and rearranging equation 26, letting the symbol Δ denote changes from point 1 to 2:

$$\Delta X + \Delta\left(\frac{U^2}{2g}\right) + \Delta(PV) + \Delta E = Q + W_F \quad (30)$$

Energy changes shown by equation 30 are:

Potential + Kinetic + Pressure + Internal = (Heat + Work) added.

The internal energy and heat added terms may be eliminated from equation 30 by using the equation relating these terms.

By equation 7 and for an ideal frictionless change $\Delta E = Q - W_B$ where W_B is the non flow or the batch work done by the system. For an actual change with friction:

$$\Delta E = Q - W_B + F \quad (31)$$

where F represents the total friction due to fluid flow. The work done by the system is given by equation 8. Combining equations 8, 30 and 31, rearranging and rewriting gives:

$$(P_1V_1 - P_2V_2) + \int_1^2 PdV + W_F = (X_2 - X_1) + \frac{U_2^2 - U_1^2}{2g} + F \quad (32)$$

The first three terms of equation 32 may be replaced by one expression, which has been derived previously and is given by equation 6. Combining equations 6 and 32:

$$\int_2^1 VdP + W_F = (X_2 - X_1) + \frac{U_2^2 - U_1^2}{2g} + F \quad (33)$$

Equation 33 is the equation of Bernoulli's theorem and applies to all fluids. For relatively non-compressible fluids, the first term in equation 33 may be replaced by a simpler expression, which is derived as follows:

$$\int_2^1 VdP = Vav\,(P_1 - P_2) = \frac{P_1 - P_2}{\rho av} \quad (34)$$

On combining equations 33 and 34 and changing pressure units to pounds per square inch, the following very useful variation of Bernoulli's equation results:

$$\frac{P_1 - P_2}{\rho av} + W_F = (X_2 - X_1) + \frac{U_2^2 - U_1^2}{64.4} + F \quad (35)$$

where: P = pressure in pounds per square foot.
ρav = average density in pounds per cubic foot.
W_F = work ("flow") added to fluid in foot-pounds.
X = height above datum plane in feet.
U = velocity in feet per second.
F = friction in feet of fluid flowing.

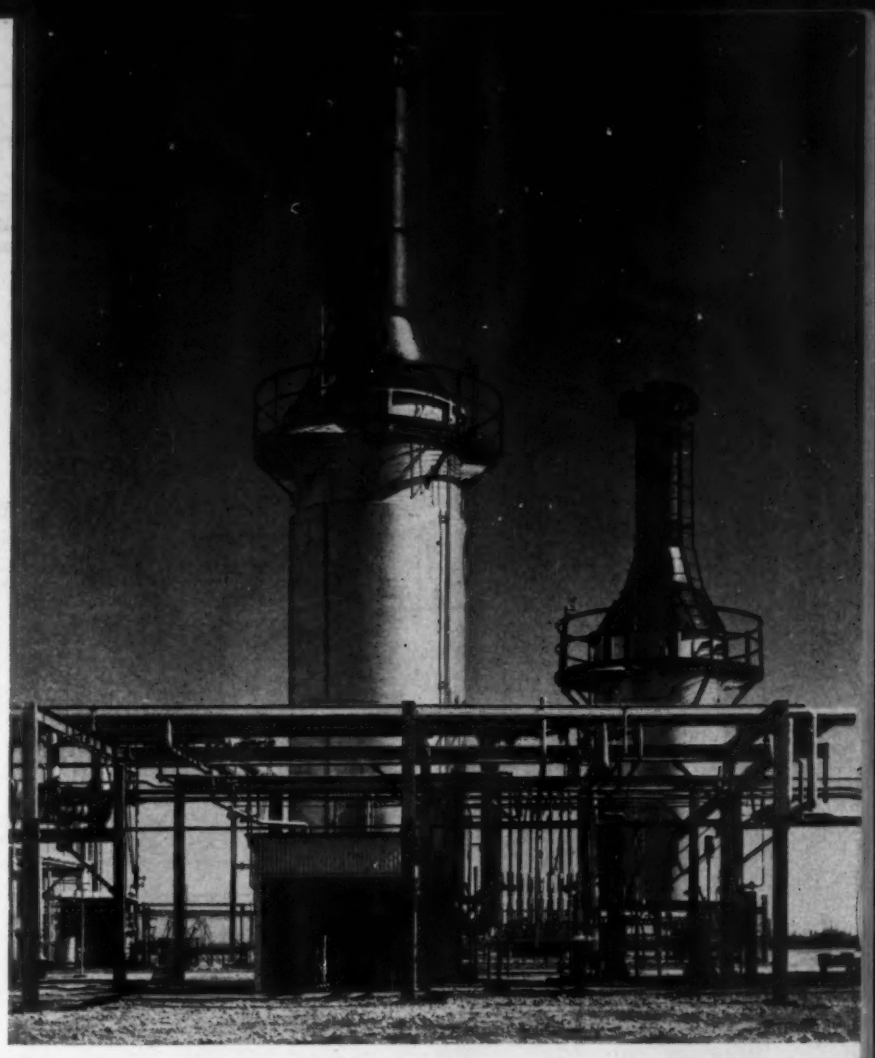
This equation applies only to relatively non-compressible fluid where the approximation of equation 34 is valid.

The steady flow systems shown in Figures 2A, 2B, and 2C indicate the range of applications of Bernoulli's Theorem.

[End of Part II; Part III will appear in the next issue.]

Control of Vertical Heaters in Gasoline Plant Operation

J. M. SAPPINGTON, Superintendent
Absorption Plant, Inc.



Furnaces showing location of instrument panel. Note steam snuffing manifold at right of panel between furnaces.

PROCESS furnaces in present day absorption-gasoline plants require "compass line" control of temperatures, pressures, and rates of flow for economic and efficient operation. In addition to the controls for operating the furnaces, safety controls and alarms must be installed to protect the equipment, and prevent shutdowns. Also, complete instrumentation for positive control of the furnace is important; however, the simplicity of the control system is a feature that should not be overlooked in order to minimize instrument supervision and maintenance requirements.

The instrument controlled operation of the vertical type, direct gas-fired high pressure rich oil and distillate furnaces in the gasoline plant at Winnie, Texas, has been adequate to provide compass line control without the use of ratio controlling mechanisms usually employed on split flow units. Although the two furnaces do not have the same capacity, they are compact units, simple in operation, which permits the use of identical instruments in a direct-acting positive control system, as shown in the diagram of Figure 1. The photograph of the control panel shows the arrangement of the instruments for both furnaces. The controls consist of temperature recording controllers and a multipoint recorder, pressure recording controllers, flow transmitters and receivers, pressure gauges, millivoltmeter pyrometers, high temperature alarms, draft gauges and solenoid valves.

Both the furnaces in service in the plant are similar in that they are vertical furnaces, direct fired with gas through directional burners, two-pass tubes of seamless carbon steel, reradiating cones of 18-8 chrome-nickel alloy supported by rods of 25-12 chrome-nickel, and cast carbon steel headers. Each furnace has a lining of 4½ inches of firebrick, 3 inches of insulating blanket reinforced by expanded metal lathe and outside shell of ¼ inch mild tank steel. The distillate furnace is smaller in size and is of radiant design; whereas, the rich oil furnace is of radiant-convection design. Construction of the furnaces minimizes radiation losses.

Maximum charge rate to the rich oil furnace is 249,100 pounds per hour of liquid having a molecular weight of 155, and 3530 pounds per hour of vapor having a molecular weight of 46. The charge has an inlet temperature of 378° F. and an outlet temperature of 460° F. This furnace is of the radiant-convection design with the top five feet of the tubes finned and the reradiating cone lowered to the bottom of the finned tubes to form a convection section. Furnace efficiency is increased in such cases where the heat load is high. At the furnace outlet, the vapor has increased to 8460 pounds per hour. The heat absorption is 14,100,100 Btu per hour with a calculated overall efficiency of 73 percent. The two-pass flow through the tubes has a maximum pressure drop of 19 pounds.

The furnace outlet temperature is controlled by a pneumatic pressure recording controller, which records the pressure of the fuel gas and actuates a conventional control valve to regulate the flow of gas to the burner manifold. An electronic temperature recording controller with the thermocouple located at the outlet junction of the two passes through the furnace resets the pressure controller. This system has the advantage of using a temperature controller to reset a pressure controller to prevent temperature

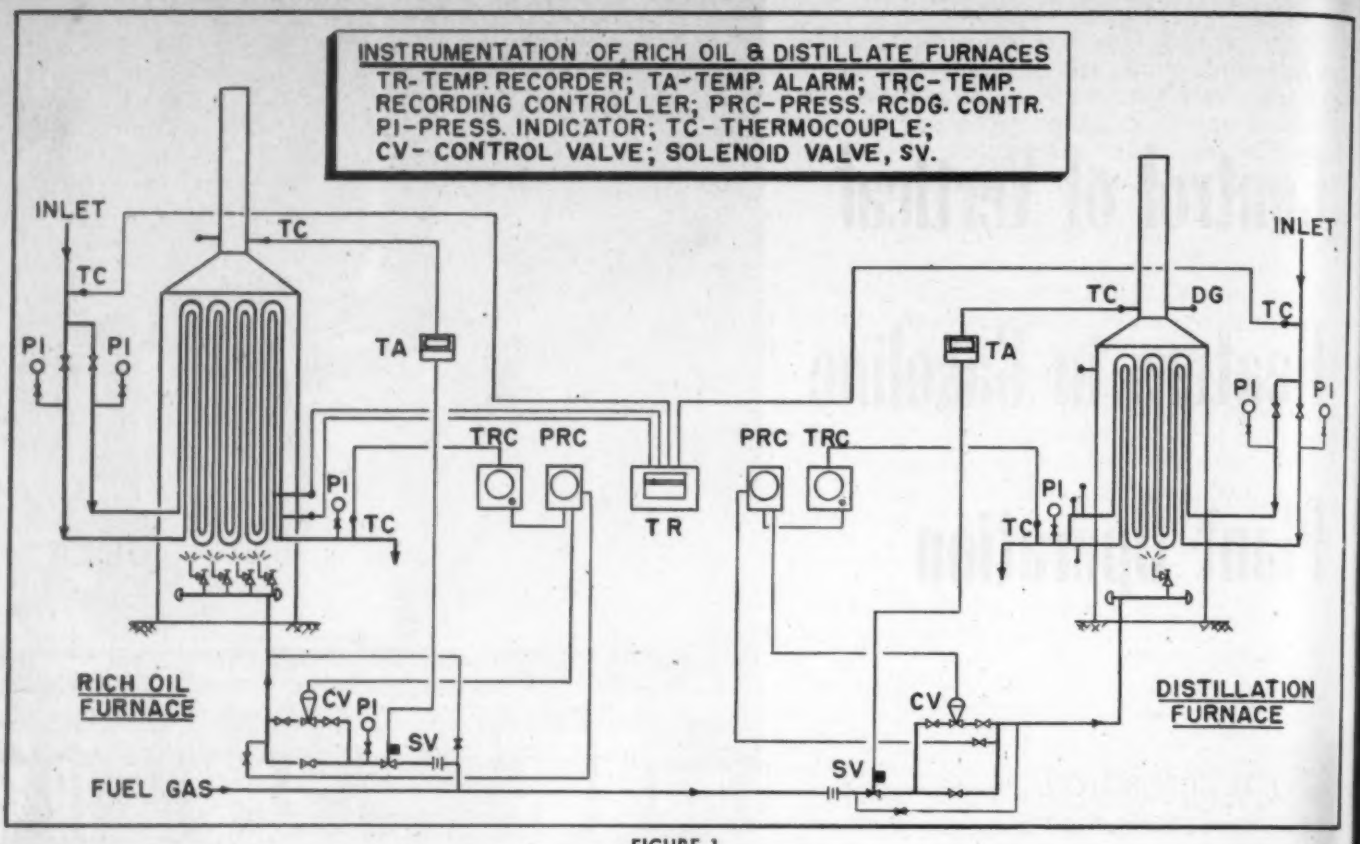


FIGURE 1

variance caused by pressure upsets in the fuel supply. Instead of waiting until this upset in fuel pressure is reflected in the furnace outlet temperature, the pressure controller corrects it immediately and prevents a lag in control. The temperature controller maintains the outlet temperature by resetting the pressure controller whenever changes in composition or rate of flow tends to upset it.

An electronic multipoint strip chart temperature recorder is used to record the inlet temperature of the furnaces and the outlet of each pass. Recording both pass outlet temperatures gives a good indication as to the flow through each pass, consequently allowing the operator to check the balance of the split stream flow, and to maintain the low pressure drop through the tubes. Gate valves are provided in the overhead inlet lines to each furnace pass with a sprocket on each valve wheel, equipped with a chain, so this flow can be adjusted. The operation is necessary only when there is a substantial change in the charge rate. Bourdon tube type pressure gauges are provided to show the pressure of the combined inlet and the individual outlet of each pass, thus showing the pressure drop through the furnace tubes.

Charge Flow Control System

Flow of rich oil to the high pressure still furnace is from the base of the low pressure vent column. The oil is picked up by centrifugal pumps and pumped through heat exchangers to the furnace. A liquid level controller on the vent column resets a recording controlling flow meter in the line which operates a control valve to regulate the flow of oil. The flow recording controller instrument is in the central control house in the plant and is equipped with a pneumatic flow transmitter, which transmits the reading of the flow meter to a receiver in the furnace control panel. This system permits both the furnace firemen and the plant operators to have records of the flow through the furnace.

Each furnace has an indicating controlling millivoltmeter pyrometer to indicate and limit the stack temperatures. This control is important because of the low draft requirements of the furnaces. The electric control units of these pyrometers actuate alarms and signal lights when the stack temperature reaches a predetermined maximum temperature. The mercury switches close and maintain contact at all temperatures above this setting, and a 110-volt current through the switches is wired to the buzzer and light to signal the high temperature condition. In addition to the alarms and lights, the pyrometer controllers operate solenoid valves on the fuel lines that shut off the gas to the burners when high stock temperatures are reached. A bypass line around the solenoid valve supplies gas to the pilot flames of the furnaces when the valves are closed. This installation has operated satisfactorily and has prevented the tubes in the furnaces from "coking up" a number of times. The system is especially valuable during electrical storms when power failures occur frequently and stop the electric motor-driven furnace charge pumps.

As an added safety precaution, a steam snuffer system has been installed. This system is manifolded in a safe location from the furnaces and provides steam lines to the fire box, each tube pass, and the stacks in an emergency. Each line and valve from the manifold to the furnaces is marked to simplify its operation.

Distillate Furnace Control System

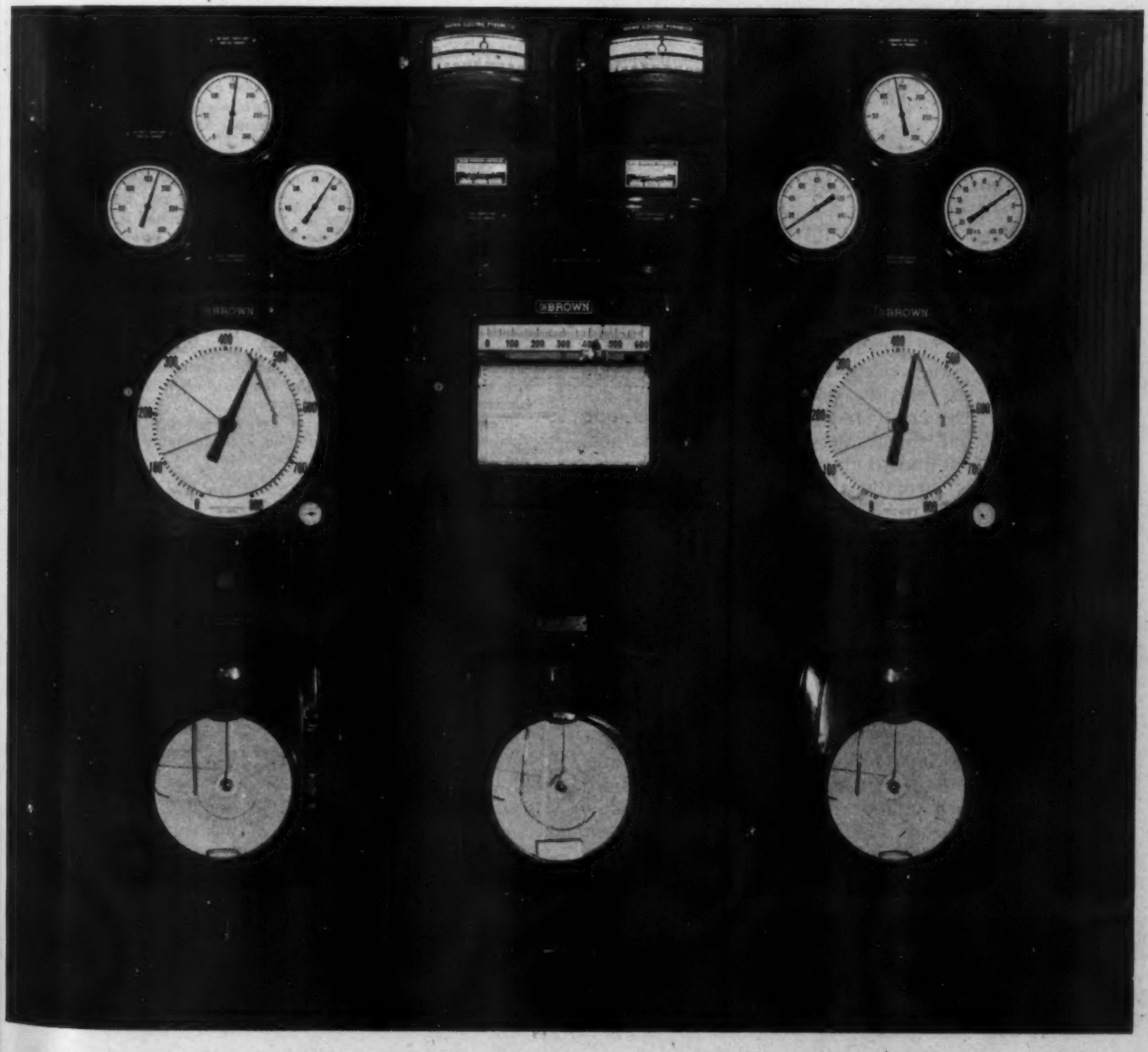
Instrumentation of the distillate furnace is identical to that of the rich oil furnace with the exception of the charge rate control and recording of the inlet temperature. The furnace has a charge rate of 19,100 pounds per hour of liquid having a 53° API gravity

and an inlet temperature of 225° F. The outlet temperature is 465° F., and 85 percent or 16,235 pounds per hour of the liquid has been vaporized at this temperature. The flow through the tubes is tow-pass with a maximum pressure drop of 15 pounds. Heat absorption of the furnace is 4,600,000 Btu per hour, and calculated overall efficiency is 61 percent.

Flow to the furnace passes through a heat exchanger taking heat from the overhead vapors of the distillate still. A recording controlling flow meter is installed in the line ahead of the exchanger and the controlled valve installed in the line between the exchanger and the distillate furnace. Thus, the flow rate to the furnace is maintained constant. The small size of the furnace does not require temperature recording other than that of the inlet. An important feature of the distillate furnace is its use for reconditioning the absorption oil. A side stream of lean oil is introduced into the furnace feed intermittently until the oil is entirely free of heavy ends and the color is clear. This operation requires only a few days each month to clean the oil system. The use of the furnace for this service eliminated installation of an oil reclaiming unit.

Temperature control instruments used on the furnaces are circular chart electronic continuous balance type potentiometers equipped with pneumatic controls. The temperature recorder is the same type potentiometer recording on a strip chart. The principal variable in the process (outlet temperature) is controlled by the electronic potentiometer or master control instrument, Figure 1, pneumatically setting the pressure recording controller, which controls the fuel pressure. This instrument has an auxiliary bellows by which the instrument control point is changed. The percentage of the instrument scale over which the pneumatically set instrument operates is manually adjusted by the operator.

The high stack temperature controllers are millivoltmeter pyrometers and have glass enclosed mercury switches to actuate the signal lights and the alarm for high temperature and the solenoid valve in the fuel line. In case of an electric power failure, the solenoid valve closes, shutting off the fuel gas. This action prevents damage to the furnaces in power failures, because the furnace charge pumps also are electrically driven.



Control panel at Winnie, Texas, gasoline plant showing arrangement of instruments for both furnaces.

Precise Laboratory Fractionating Column

HOMER J. HALL and F. LOWELL JONACH
Standard Oil Development Company

THE complete analysis of any complex hydrocarbon mixture requires a preliminary distillation. When the content of individual hydrocarbons is to be determined by optical methods in the range of C_7 to C_8 paraffins and C_8 to C_9 aromatics, this requires an efficiency adequate to concentrate compounds boiling 1 to 4° F. apart, and to separate entirely certain interfering pairs boiling 10 to 40° F. apart.

A battery of adiabatic stills having a capacity of 200 ml have been designed and built for this purpose at the Esso Laboratories. The average time to complete a run is about 43 hours, including an acetone wash and drying-out period. Routine distillations of hydrocarbons boiling as high as 380° F. are conducted without column heating.

On a test with nheptane-methylcyclohexane the theoretical efficiency of these columns reaches 80 plates and levels out in 3 to 4 hours. In actual use the separation attained is enough to show enrichment of C_8 isoparaffins boiling as little as 0.6° F. apart.

Each column contains a 22-inch packed section of 3/64-inch Fenske helices, with an operating holdup of 8 ml, and a boilup rate of 150 ml per hour. Pressure drop at the flooding point is about 2.5 mm of mercury with a paraffinic charge or 4.5 with an aromatic. Adiabatic conditions are maintained by a shielded vacuum jacket, containing a layer of aluminum foil supported directly on the outer surface of the distillation tube. Details of construction and assembly are given.

Presented to the Division of Refining's Symposium on High-Temperature Analytical Distillation, 25th Annual Meeting, American Petroleum Institute, November, 1946.

CURRENT developments, as reflected in the present symposium, show remarkable agreement between various authors on what makes a good distillation column. The design and construction of such equipment can no longer be considered as a black art, and in the future it can be expected that more and more columns will be built to do a specific job, designed for the purpose. The 200-ml adiabatic stills described in the present paper are an example of such equipment.

At the beginning of the war, work on the analysis of synthetic aviation-fuel blending agents became increasingly important. It was obvious that an adequate method of analyzing these materials would be an invaluable research tool in the control and improvement of product quality. The method developed and used for this purpose in the Esso Laboratories was a combination of distillation and infrared analysis.[1] Results were reported in terms of percent by volume on total sample for each of 24 paraffins, in the range C_5 to C_9. These analyses were actually used to calculate octane numbers and rich-mixture performance on 200-ml batches of experimental batches of alkylates and hydropolymers, and the octane-number data obtained in this way were found to check quite closely the results of actual performance tests.

Important savings in time and technical manpower resulted from the use of this procedure. To realize the full advantage, however, it was necessary that sample size and distillation time be kept at a minimum consistent with the high accuracy desired.

Design Requirements

The distillation equipment described herein was designed to fit into these requirements. The principal design factors considered are a small charge, a high number of plates, adequate throughput, low holdup in the column and head, and the ability to handle smoothly the sharp temperature breaks which result from clean separation. The basic design was chosen to take a charge of 200 ml plus chaser. This amount is readily produced in an experimental alkylation or polymerization run. One-percent cuts on such a charge give 2 ml of material, which is enough for infrared analysis plus a refractive index, bromine number, aniline point, or carbon-hydrogen analysis if necessary.

Efficiency requirements are set by the infrared analysis. This distillation prior to optical inspection serves several purposes:

a) To reduce the number of components to be considered in a single cut.
b) To separate major components which cause mutual interference.
c) To segregate trace components (such as triptane) into narrow fractions of high concentration.
d) To minimize the effect of extraneous impurities.

For analyses in the range of C_7 to C_8 paraffins and C_8 to C_9 aromatics, this requires an efficiency adequate to concentrate compounds boiling 1 to 4° F. apart, and to separate entirely certain interfering pairs boiling 10 to 40° F. apart. About 80 theoretical plates are needed to give a 99-percent separation of compounds boiling 10° apart.

Time on stream is a function of total charge, throughput, and reflux ratio. In alkylate and hydropolymer analyses the reflux ratio used was 50 to 1 where separation was critical, 10 to 1 on major

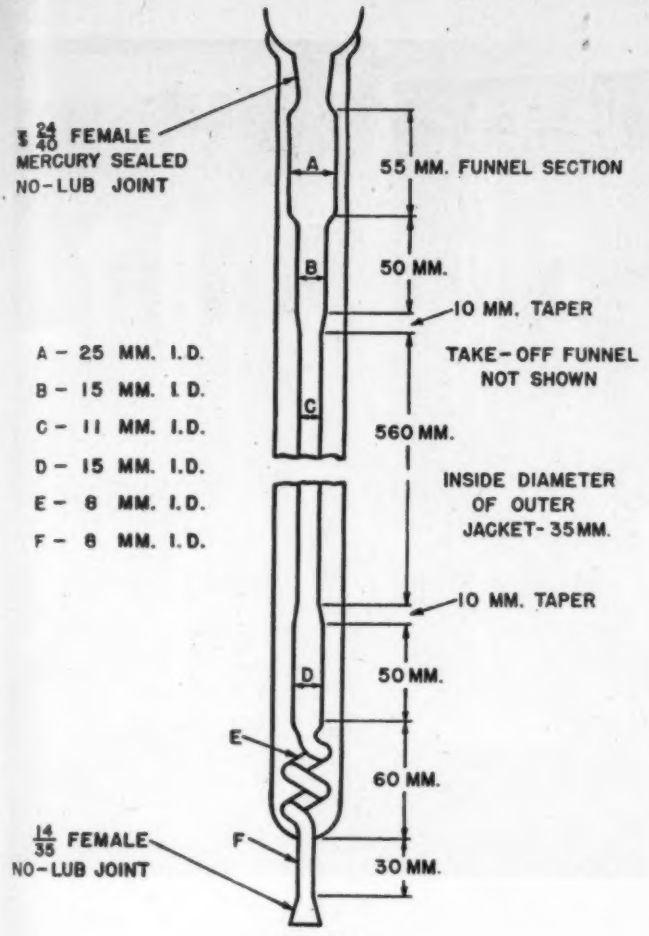


FIGURE 1
Distillation Column

plateaus, and an average of about 20 to 1 throughout the distillation. Maximum throughput short of flooding was about 150 ml per hour, and the columns were operated at about 70 percent of this value, or 100 ml per hour.

The effect of column holdup on the separation of minor constituents is critical, and especially so in a column using a small charge.[2] The 8-ml holdup of these columns is equivalent to 4 percent of charge. Small column holdup is also important in determining the time factor relating reflux ratio and time on stream, as a large ratio of holdup to throughput requires a longer time to reach equilibrium, and a high reflux ratio to effect a given separation. An independent factor of holdup is the total amount of material between the takeoff point and the top of the separating zone. This is kept to the very minimum, to avoid remixing of the separated products from the top of the distilling tube.

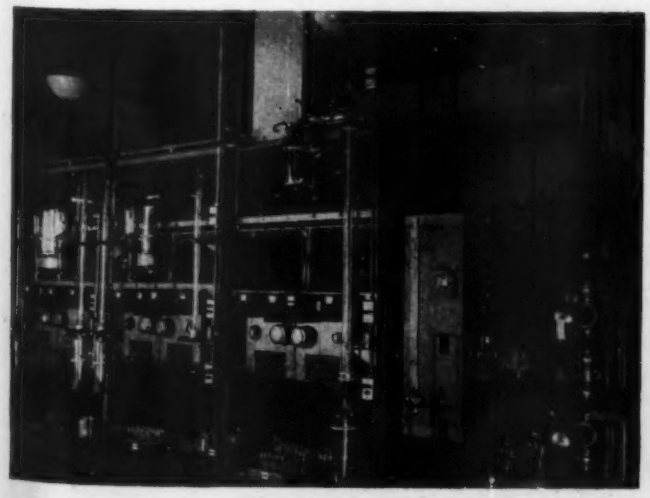


FIGURE 2

The factor of low heat loss is particularly important in small-scale equipment, and its effect is more noticeable the sharper the separation required. An adiabatic system having substantially no heat lost to or from the column is important, because any arrangement which depends upon heat transfer to correct heat lost from the column will upset to some extent the normal temperature gradient in the distilling tube. The thermal insulation in these columns was obtained by using a highly evacuated jacket containing a reflecting metal shield of aluminum foil.

Construction

The unit finally designed on these considerations is shown diagrammatically in Figure 1. The distilling tube proper is a Fenske column, 11 mm in diameter and 560 mm or 22 inches long, packed with 3/64 inch stainless-steel Fenske rings.[3] This tube leads directly into the splitter section A. The expanded disengaging sections B and D serve to prevent flooding at the top and bottom of the column, respectively. The glass expansion coil E was designed and mechanically tested to take up the thermal strain developed when the distilling tube is at a temperature of 400° F., with the outside jacket at room temperature. The packing is supported on a cone of stainless-steel wire gauze placed at the top of the glass expansion coil, between D and E. Allowing for the effect of the disengaging sections, this assembly gives a height per theoretical plate of a little less than 8 mm, or 3½ plates per inch.

A vacuum jacket surrounds the entire column, including the expansion coil and the takeoff section up to the level of the condenser. Thorough evacuation is critical, and the column is baked out under vacuum for 48 hours in an annealing oven before sealing off. This cuts down heat transfer by conduction, and radiation losses are cut by a metal shield of very low heat emissivity (high conductivity). Aluminum is preferred over silver or copper (which are theoretically as good) because it more easily maintains its polished surface during fabrication. This shield is supported directly on the top and bottom disengaging sections of the distilling tube, and it does not interfere with visual observation of the takeoff section.

The general appearance of the still battery constructed is shown in Figure 2. Space is provided for 6 units. Four of the 200-ml size, and one of 1-liter capacity are shown. Design of the 1-liter unit is essentially similar to the 200-ml size, except that the packed section is 45 inches of 1/16-inch rings in a 15-mm tube, with 22-mm-inside-diameter disengaging sections and corresponding changes in other dimensions.

Particular attention is directed to the inverted joint between the still pot and the bottom of the column, also shown in Figure 3. At the end of any run the pot is much hotter than the column, and a conventional joint with the female half on the pot often shrinks firmly onto the column as it cools. Placing the male section on the pot and the female on the column causes the pot to shrink away from the column, so

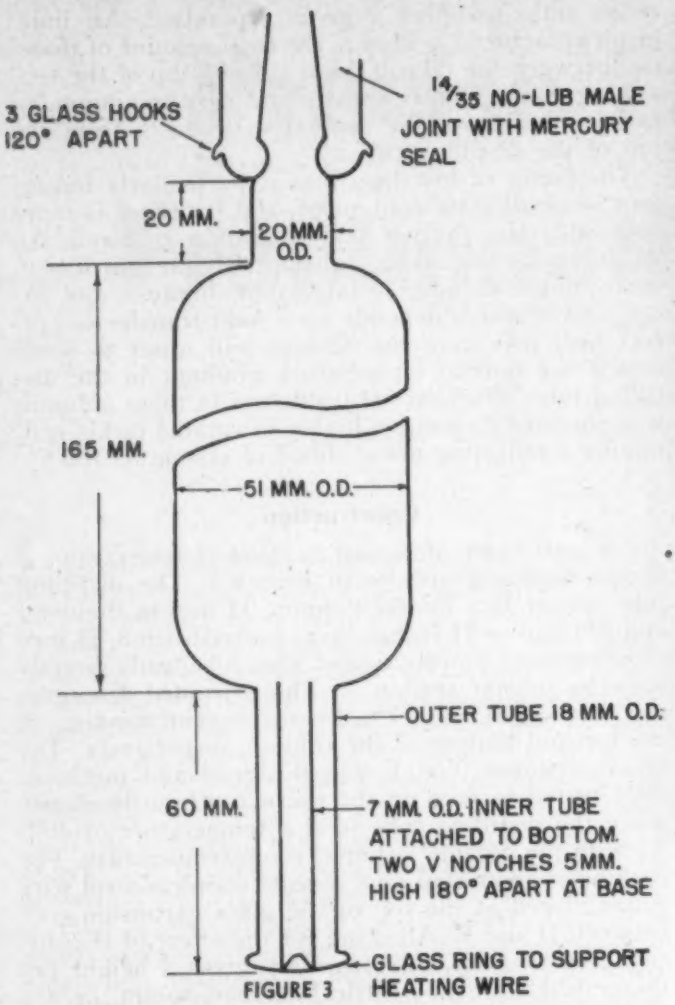


FIGURE 3
Still Pot

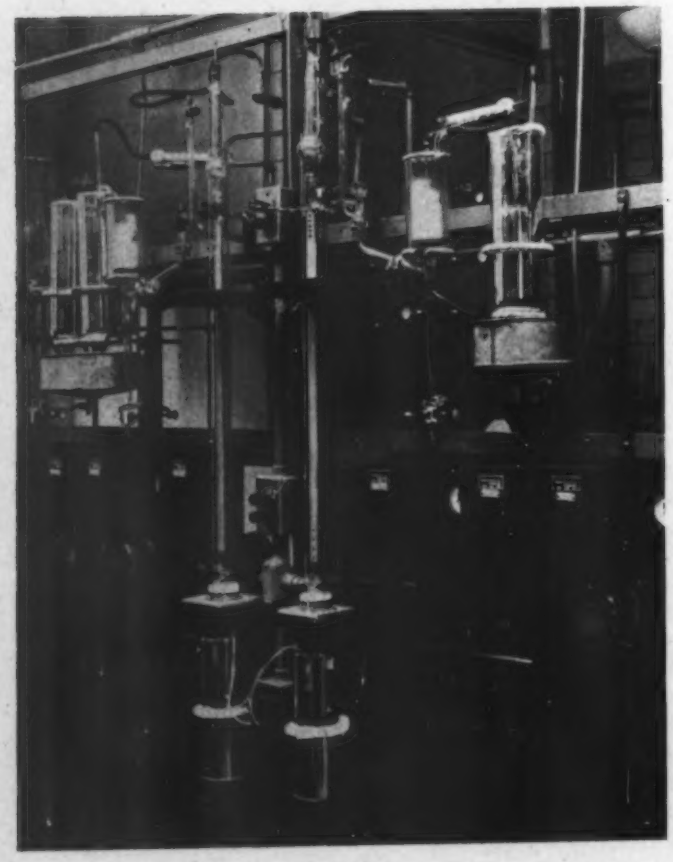


FIGURE 4

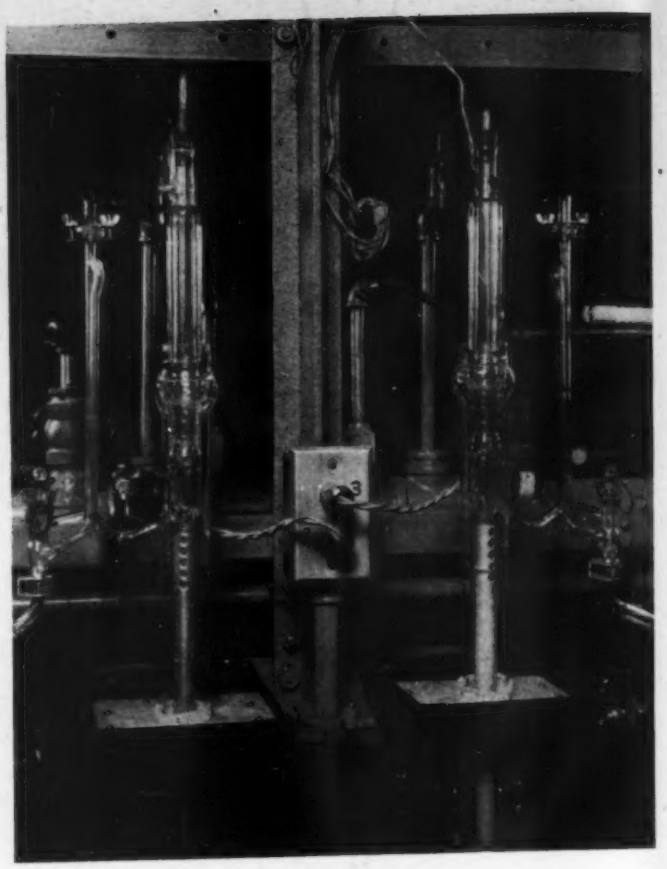


FIGURE 5

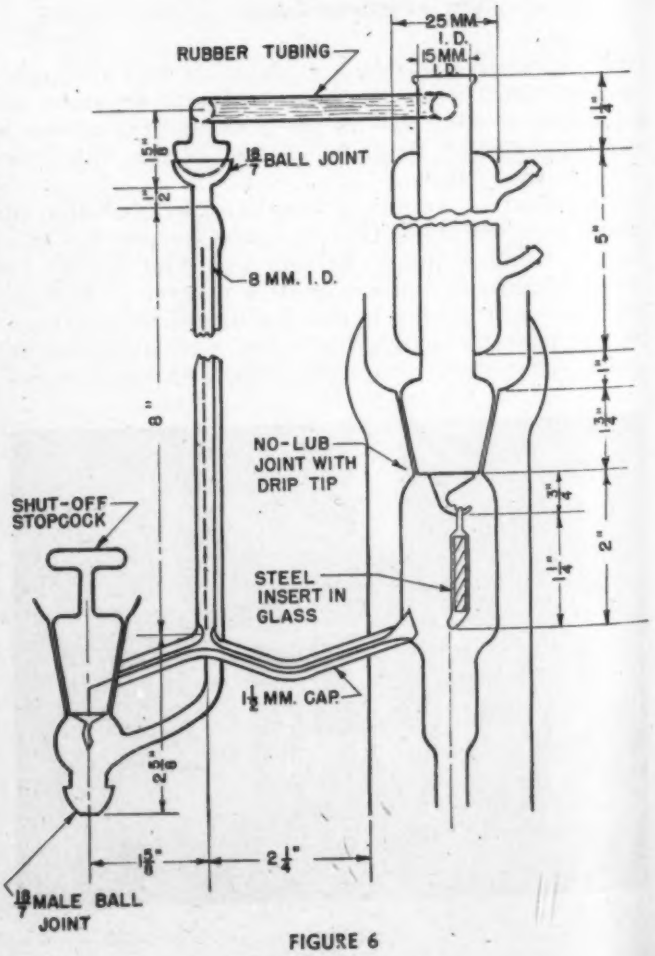


FIGURE 6
Distillation Column

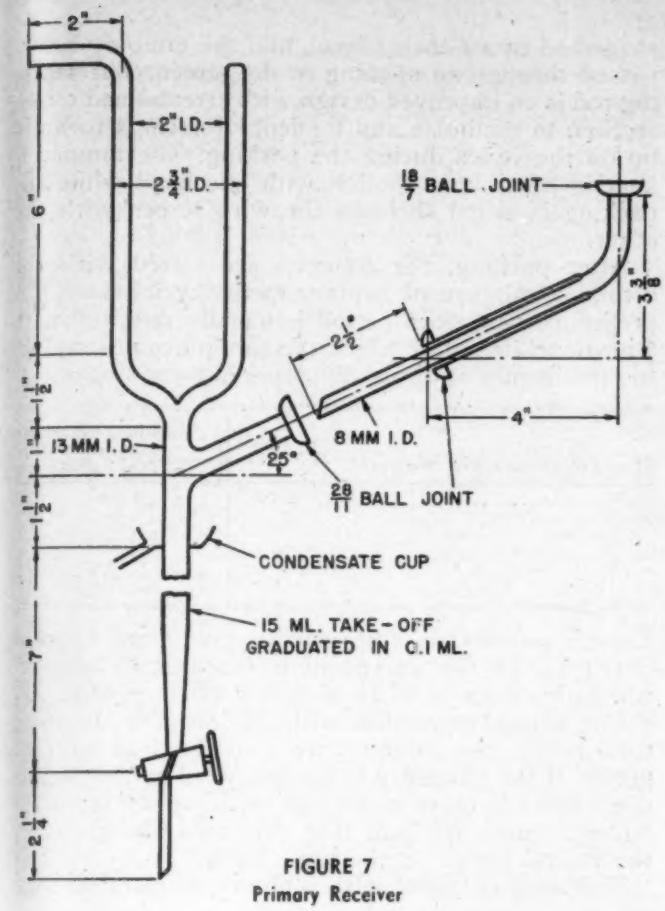


FIGURE 7
Primary Receiver

the danger of pot sticking is practically eliminated. The use of the specially ground "No-Lub" joints[4] has been found entirely satisfactory, and the still pot is mounted on the column without any lubricant. The heating element is cemented on the outside of the heating leg as indicated, with no exposed wire. The inner thermal siphon tube has been found to prevent bumping in any samples, except those containing substantial amounts of dissolved water. The whole unit is mounted in a standard 1-liter Dewar flask, to minimize heat losses. The design of the still pot and distilling tube shown are based on specific suggestions by M. R. Fenske.[5]

Figure 4 shows a closeup view of columns 2 and 3 with their auxiliary equipment. Still pots, receivers, butane traps, and electric panel boards are all interchangeable, and spare parts are kept on hand to eliminate shutdowns wherever possible. Actual experience has shown that it is possible to remove the panel board with all electrical controls, and to substitute a new one in the middle of a distillation in less than a minute elapsed time.

A detailed closeup of the column head and takeoff sections is shown in Figure 5, and a working drawing in Figure 6. The packing comes up to within a few millimeters of the takeoff funnel, and the condenser tube extends down into this section. The reflux stream flows along the dripping rod in the same manner as liquid flowing along a stirring rod held at the edge of a beaker. The single-point suspension from a hook on the bottom of the condenser eliminates trouble with a sticking funnel, which is the main objection to the swinging funnel type of head.[6] Additional pull for the magnetic deflection of the dripping rod is obtained by using a carbon-steel insert and a direct-current solenoid. The "No-Lub" joint on the condenser gives easy access to the working part of the column for critical minor adjustments during construction, without adding extra holdup in the takeoff section. It also leaves an unobstructed open tube for adding or removing the packing. The condenser tube and vent lines are designed to handle emergency loads as well as routine preflooding.

When the dripping rod is actuated by the solenoid, the reflux stream is diverted into the funnel and drips from the modified Newman valve[7] in the shutoff cock into the adapter and receiver assembly shown in Figure 7. This is designed to minimize holdup and prevent contact of the product stream with the surfaces of the ground-glass joints, which are lubricated with glycerin. The two ball joints on a 65-degree angle permit lateral or vertical adjustments as required during assembly. The small condensate cup serves to trap moisture which runs off the outer surface of the condenser on summer days when the humidity is high.

Operation

The advantages of adiabatic operation appear first in the fact that no column heating is required. The outside of the vacuum jacket is cold to the touch at overhead temperatures up to 300° F., and becomes just warm at 350 to 380° F. A more spectacular demonstration appeared when one column was jacketed with a heating unit to permit operations to 500° F., and it was found that a jacket temperature of 400° F. had no effect on the distillation of a stream of pentane refluxing through the column at 96° F. Clean temperature breaks as sharp as pentane to *iso*octane (Δ boiling point = 114° F.) or toluene to cymene (Δ boiling point = 117° F.) cause no disturbance in operation. The chaser normally used for C_8-cut analyses is a 365- to 395° F. aromatic fraction boiling 100° above the bottoms of the sample.

Operating pressure drop was found to be 1.2 to 1.5 mm of mercury with a normal alkylate sample. This shows wide variation with changes in boiling point and composition, however. At a rate of 150 ml per hour boilup, the ΔP for a C_8 alkylate is 2.5 mm of mercury; whereas C_{12} is 3.5, benzene 3.6, toluene 3.9, and xylene 5.0. This situation is not favorable to an automatic pressure-drop control. In fact, the units were operated on the theory that the fewer the gadgets, the less the downtime. The original design shown in Figure 2 and 4 called for a barostat, column heat, and pressure-drop control. When the columns were first assembled, they were tried without this equipment; after 3 years of operation, it is still used seldom, if ever. One operator runs 3 to 5 stills at a time, charging and cleaning out, taking fractions, measuring and recording temperatures. The only operating controls are the reflux timer and a Variac on the pot heat. The operator keeps track of the boilup rate by counting drops from the dripping rod at the time when each cut is taken, and adjusts the Variac to maintain a rate of 90 to 100 drops per minute. This setting is normally changed 6 to 8 times during the course of a 30 to 40-hour distillation. Distillations are commonly run to a dry pot, or to a predetermined overhead temperature using a chaser.

Time on stream averaged 38 hours for 132 distillations completed in the first 18 weeks of operation. This includes an hour for warming up and preflooding twice, plus three hours on total reflux to reach equilibrium efficiency.

One point which may be of general interest is the

FIGURE 8

use of dry ice in the receiver condenser head with no solvent. The common accident of slopping solvent over the edge of the container when adding more dry ice would be particularly unfortunate in a receiver head. It was found that the dry ice without any solvent is so efficient that 5 ml of butane condensed in the receiver can be warmed up to vigorous boiling without forcing any butane past the condenser into the auxiliary trap.

The most critical point in operating technique for anyone who proposes to set up equipment of this type is the care with which the columns are packed. It is possible to get anywhere from 20 to 95 plates on one of these columns, depending upon the packing job done. The importance of Fenske's recommendation that the rings be tamped firmly and evenly in place as they are added to the column cannot be overemphasized. An uneven packing job will affect both the efficiency and throughput, and a column packed without tamping gave 45 plates in one case. The total time required to take down a column and clean out the packing, reassemble, and repack is about a day, but the actual time required to introduce the packing is 45 minutes to 1 hour. The equipment used for this purpose is shown in Figure 8. We are grateful to Mr. Willingham of the National Bureau of Standards for the suggestion that the Fenske rings can be readily separated by sifting through a wire screen. In the equipment shown an ordinary piece of wire gauze is shaped to fit a 6-inch funnel, and the tamping rod is passed through an opening in the screen. The tamping rod is an improved design with streamlined cross-section, to minimize any tendency for rings to build up on the vanes during the packing. The tamper is kept in continuous motion with one hand while the packing is sifted through the wire screen with the other.

. After packing, the columns are tested with the orthodox mixture of heptane-methylcyclohexane.[8] A preliminary break-in period is usually required with a new packing, after which the column comes rapidly to equilibrium at about 80 plates in 3 to 4 hours.

Time After Preflooding (Hours)	Theoretical Plates in Column on Total Reflux
1	30
2	55
3	73
4	80
5	81
8	82

Longer periods on test usually give pure heptane overhead. If the composition is carefully chosen, ultimate values of 85 to 95 plates are obtained.

For normal operation with an initial 3 hours on total reflux, the columns are considered to have 80 plates. If the efficiency is markedly below this figure, the column is taken down and repacked. Data on the 1-liter column indicate that this unit has about 90 theoretical plates on the same basis.

Test data obtained with a binary mixture on total reflux can be misleading. The effects of adequate heat control, and time to reach equilibrium, may be overlooked entirely. These factors become vitally important as more complex mixtures are used in actual

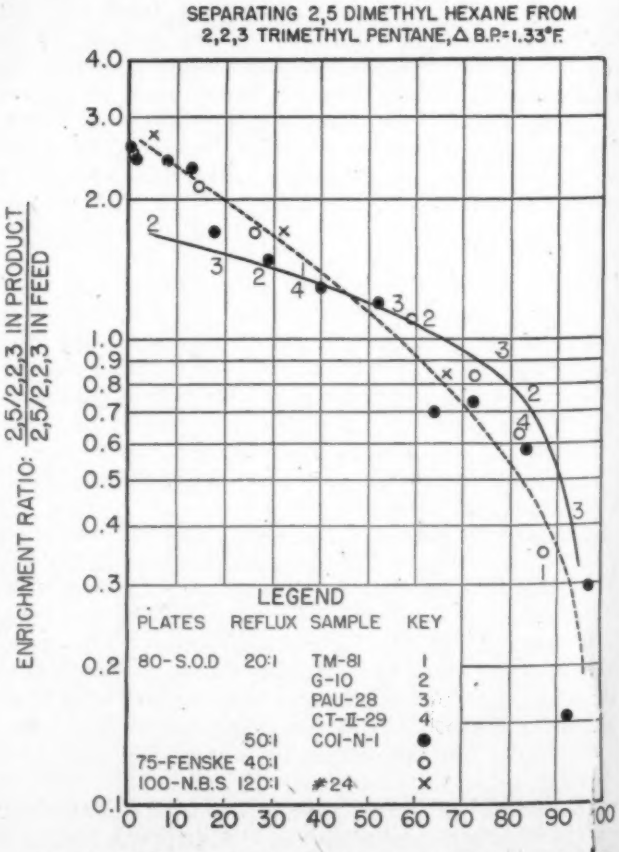


FIGURE 9

Column efficients in terms of enrichment ratios

TABLE 1

Separations Obtained in 80-Plate Column at 20-to-1 Reflux (Percent by Volume by Infrared)

Sample G-10, cut No.		19	20	21	22	23	24 to 25	26 to 29
Cumulative volume (percent)		46.6 to 51.7	56.9	62.0	67.0	72.1	74.8	83.0
Cut volume (percent)		5.1	5.2	5.1	5.0	5.1	2.7	8.2
COMPOUND	Boiling Point (Degree F.)							
2,2,4-	210.6	100	72	0	..	..	..	..
2,5-	228.4	...	8	30	23	8	1	0
2,4-	229.0	...	10	23	20	10	5	1
2,2,3-	229.7	...	10	46	46	24	15	7
2,3,4-	236.3	...	..	1	9	30	31	21
2,3,3-	238.6	...	..	0	2	28	45	64
2,3-	240.1	...	..	..	..	..	3	7

TABLE 2

Enrichment Ratios at 50-to-1 Reflux on 2,5-Dimethylhexane—2,2,3-Trimethylpentane Plateau of Sample COI-N-1

HYDROCARBON	Boiling Point (Degree F.)	Percent by Volume of Analysis at Indicated Percent on Plateau						
		1	2	10	20	50	80	90
2,5-Dimethylhexane	228.38	7	13	27	24	21	10	2
2,4-Dimethylhexane	228.97	4	11	29	37	44	30	17
2,2,3-Trimethylpentane	229.71	3	6	13	17	21	20	15
2,5- to 2,2,3- in product	.....	2.4	2.2	2.1	1.5	1.00	0.50	0.13
2,5- to 2,2,3- in feed	0.86	..	..	..	..	..	..	..
Enrichment ratio: 2,5- to 2,2,3- in product / 2,5- to 2,2,3- in feed	.....	2.7	2.5	2.4	1.6	1.16	0.58	0.15

practice. Now that such complex mixtures can be analyzed by spectrographic methods, a more significant measure of column performance is available. One such set of data in the C_8 paraffin range is shown in Table 1. Considering 2,5-dimethylhexane and 2,3,3-trimethylpentane as a set of components boiling 10° F. apart, cut 22 shows 2 percent of the higher-boiling material, whereas in cuts 24 to 25 there is 1 percent of the low-boiling isomer. These 2 fractions are separated by 5 percent on sample, representing approximately 1 column holdup. The data thus indicate that at 20-to-1 reflux the desired separation of compounds boiling 10° F. apart is obtained in 98 to 99-percent purity.

The ultimate criterion for judging performance in any column is its ability to segregate and concentrate, in narrow product fractions, feed constituents present in small amount and boiling close together. On this basis the 3-component plateau of 2,5-dimethylhexane, 2,4-dimethylhexane, and 2,2,3-trimethylpentane boiling at 229.0 ± 0.7° F. was chosen for further study. In every case the ratio of the more-volatile to less-volatile compound in successive distillation cuts shows a regular pattern. With 2,5-dimethylhexane and 2,2,3-trimethylpentane, for example, we have first a ratio of 1 to 1, which increases up to 1 to 2 and to 1 to 15 in successive fractions. This regularity is used to check the accuracy of both the distillation and infrared results.

The same data may be used still further on a mathematical basis. If the amount of 2,5-dimethylhexane relative to 2,2,3-trimethylpentane is measured for each cut, the ratio shows a consistent trend throughout the plateau. This ratio in each cut is then divided by the ratio of the same components in the original sample. Such a set of data is shown in Table 2 for the 2,5-dimethylhexane–2,2,3-trimethylpentane plateau of another sample.

The final "enrichment ratio" obtained permits a direct comparison of column operation with different feeds, regardless of the analysis of the charge. The solid line in Figure 9 corresponds to numbered points representing the enrichment ratio obtained at 20-to-1 reflux in 4 different runs. Although the total amount of material in the plateau varied from 2 to 20 percent (0.5 to 5 column holdups) and the ratio of 2,5 to 2,2,3 in the originals varied from 1.9 to 0.38, all 4 runs are represented by a single correlation line. The data indicate that, at the beginning of the plateau, the enrichment of these compounds boiling 1.3° F. apart is 2 to 1, and at the end of the plateau about 1 to 2. The effect of reflux ratio is shown by the dotted curve presenting the data from Table 2. Operating at 50-to-1 reflux shows a definite improvement over 20 to 1.

Data from similar samples have been calculated for the 75-plate Pennsylvania State College barrel still,[5,9] which is essentially adiabatic by virtue of its size, and for the silvered vacuum-jacket column used by API Research Project 6 at the National Bureau of Standards in distilling alkylate sample No. 24.[10] These data check the 50-to-1 correlation line, and indicate that 120-to-1 reflux in an 80 to 100-plate column has little advantage over 50 to 1 when the relative volatility of the 2 components is as low as the 1.021 which characterizes this separation.

Acknowledgment

The authors wish to express their appreciation to Dr. M. R. Fenske of the Petroleum Refining Laboratory at The Pennsylvania State College for many of the suggestions and data used in designing and testing these columns. All glass blowing was done by Walter Schaefer at the Esso Laboratories.

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Design and Operation of a Small-Scale Thermofor Catalytic Cracking Unit

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Houdry Process Corporation

THE Thermofor Catalytic Cracking unit of Leonard Refineries, Inc., Alma, Michigan was put on stream March 18, 1947. Considering the effective utilization of existing equipment, the costs of material and construction and the results of the first three months' operation, the plant is an outstanding demonstration of the feasibility of catalytic cracking for the small refiner.

ADAPTATION of catalytic cracking equipment into existing refining facilities of the small classification has been one of the essential developments of the postwar period. Demand for military gasolines made it imperative that the early catalytic units be designed for high output, which required that the installations be in the larger refining centers.

That situation was perplexing to the owners of plants of the 10,000-barrel class, who realized that they would of necessity have to meet the competition of these large units on a peacetime basis. Owners of the catalytic processes were prompt to predict the successful design of units of the smaller classification.

This article is a report on an installation in one small plant as presented before the technical meeting of the Western Petroleum Refiners Association in Alma, Michigan, July 16, 1947.

Process Design

The plant was designed to process 4500 barrels per day of reduced Michigan crude from which a reactor charge of 3000 barrels per day would be derived. These rates were fixed by the capacity of existing auxiliary equipment, the use of which was paramount in all design considerations. However, the catalytic equipment was purposely oversized to permit a future reactor charge of approximately 6500 barrels per day. For all practical purposes it may be considered that the catalytic reactor and regeneration kiln merely supplanted the reaction chamber of an existing thermal cracking unit. Through careful planning, the existing thermal cracking raw charge pump, heat exchangers, light and heavy oil cracking furnaces, flash chamber, fractionating tower, absorption column and stabilizing column were all utilized in preparing the unit to function as a catalytic cracking plant.

The process flow for the catalytic section is shown schematically in Figure 1. The reduced crude charge is picked up from storage tanks and after passing through conventional heat exchange equipment is partially vaporized in the former light and heavy oil cracking coils. When the first design studies were made it was found that the pressure drop through the heaters would be excessive. To overcome this condition, the tubes were rearranged so that each heater now has two parallel coils for the heating and partial vaporization of the charge. From the heaters the partially vaporized reduced crude enters the former thermal cracker flash chamber which is now employed as a tar separator.

From this vessel, which operates at a temperature of 825° F. and a pressure of 7 PSIG, 70 percent to 80 percent of the reduced crude is flashed overhead as reactor charge. The bottoms from the tar separator are used in heavy fuel oil blends or charged to a vacuum tower for the production of asphalt. Steam, employed in the tar separator to assist in the vaporization of the reduced crude or charged to the reactor vapor inlet line, is super-heated in separate coils located in the convection section of each heater. The steam is superheated to a temperature of approximately 900° F. and the quantity amounts to about 3100 pounds per hour or 8 percent by weight of the reactor charge.

The oil vapors from the tar separator enter the top of the cracking reactor where they come in contact with regenerated catalyst. The catalyst and oil vapors flow concurrently downward through the reactor and are withdrawn from the bottom of the vessel as separate streams; the catalyst passes to the elevator for return to the regenerating kiln while the oil vapors are directed to the fractionation system.

Fractionation

In catalytic cracking operations the total hydrocarbon stream leaving the cracking reactor is commonly called "synthetic crude." On the Leonard unit these vapors are fractionated into gasoline and gas, distillate fuel oil and heavy gasoil in a bubble tower formerly used in the thermal cracking unit. The overhead from the tower is cooled and partially condensed in a barometric-type, direct contact condenser from which unstabilized gasoline and rich gas are withdrawn. The latter is compressed to 75 PSIG in two 2-stage, 225 horsepower gas compressors, cooled and contacted with the unstabilized gasoline. This processing scheme was adopted in order to utilize to the best advantage the existing gas plant recovery equipment. The gas from this operation enters a 16-plate absorption column for which the supply of lean oil is a portion of the distillate fuel oil fraction drawn from the synthetic crude fractionating tower. The rich oil from the absorber is returned to the synthetic crude tower and serves as an intermediate reflux,

while the dry gas from the absorption column enters the refinery fuel system. The gasoline from the contactor cooler is pumped to a 24-plate stabilizer where its vapor pressure is adjusted to approximately 10 psi. The overhead from the stabilizing column is sent to a depropanizer where it is separated into a C_4 fraction as bottoms and C_3 and lighter hydrocarbons as overhead. The latter stream is then fractionated in a deethanizer for the production of a purified propane fraction sold as liquefied petroleum gas.

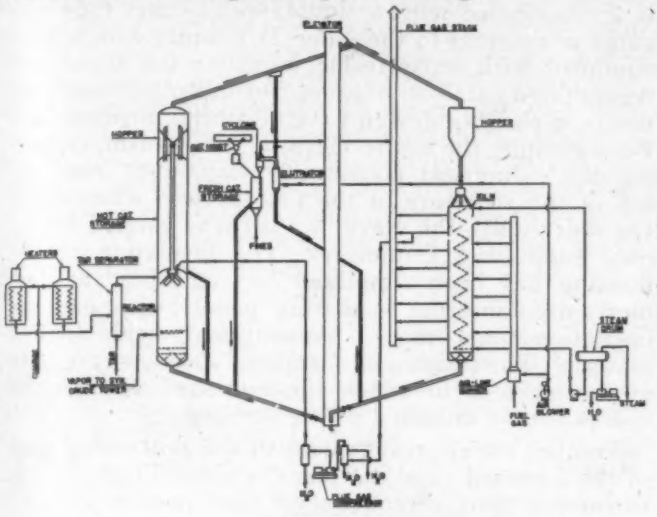


FIGURE 1
Catalytic Section Flow Diagram

Continuous circulation of catalyst is maintained by a single, 153-foot, endless chain, bucket-type elevator which transports both spent and regenerated catalyst from the bottom to the top of the structure. Each elevator bucket is divided into three compartments, the combined volume of the two outer compartments, which carry spent catalyst, being equal to the volume of the center compartment which carries regenerated catalyst. The elevator has a design capacity of 150 tons per hour which provides for the circulation of 75 tons per hour of spent catalyst to the kiln and 75 tons per hour of regenerated catalyst to the reactor. At reactor charge rates in the neighborhood of 3000 barrels per day, the 75 tons per hour of catalyst circulation is equivalent to a volumetric catalyst to oil ratio of approximately 4.5 to 1 which is the volume of catalyst circulated per hour divided by the liquid volume of oil charged per hour to the reactor.

Regenerated catalyst flowing downward through the reactor accumulates a carbonaceous deposit in the reaction zone which temporarily reduces its catalytic activity. Thus, the catalyst flowing out of the reaction zone is normally referred to as "spent," and must be regenerated to restore its activity. Spent catalyst flowing through a central outlet line from the bottom of the reactor is split into two streams which enter the elevator casing through specially designed control valves known as "chopper" valves. The divided stream of spent catalyst is directed into the two outer compartments of each elevator bucket and carried to the top of the structure where it is discharged into chutes leading into a hopper above the regenerating kiln. From the kiln hopper the catalyst flows downward through a circular distributing device into the kiln proper where the carbonaceous deposit or coke is removed by controlled combustion with air. The catalyst is regenerated in seven alternate burning and cooling zones and the excess heat of combustion is removed by the generation of 290 pounds steam. Boiler feed water is continuously circulated through coils located between burning zones and returned to a steam flash drum. Since the rate of water circulation is several times that of the steam production the degree of vaporization occurring in the coils is sufficiently small to prevent the deposition of boiler scale. Regenerated catalyst flows from the bottom of the kiln in a central outlet line through another chopper valve into the center compartments of the elevator buckets which carry it to the top of the structure where it is directed into the reactor hopper to repeat the cycle of flow through the system.

The catalyst circulation rate may be varied by adjusting the position of the chopper valve in the kiln outlet line. When a change in catalyst flow rate out of the kiln is made in this manner, the flow of catalyst out of the bottom of the reactor is automatically adjusted to an equivalent rate by means of a level-indicator-controller in the reactor hopper which actuates the chopper valves in the reactor catalyst outlet line.

Several innovations have been made in the design of the Leonard plant not only to reduce investment costs but also to improve the performance of the unit. The overall height of the catalytic section has been reduced about 50 feet below that of older installations. Also, the catalytic section occupies only about 1250 square feet of ground area and therefore was erected at the site of the former thermal cracker without changing the location of existing equipment.

The reactor catalyst hopper, the hot catalyst storage bin and the reactor are parts of a single, self-supporting cylindrical vessel. The hopper, occupying the top portion of the vessel, is connected to the reactor proper, which occupies the lower portion of the vessel, with a 45-foot long catalyst seal leg and the intermediate space surrounding the seal leg is utilized as the hot catalyst storage bin.

The 12-foot diameter reactor is designed especially for concurrent flow of oil and catalyst, a development proven in several operating units. With this type of flow both the catalyst and oil vapors are introduced at the top of the reactor and pass downward through the reactor. The vapors are disengaged from the catalyst at the bottom of the reactor catalyst bed in a device designed to prevent the entrainment of particles of catalyst in the effluent vapor stream. The reactor is designed for amaximum catalyst bed depth of 15 feet and is arranged so that with only minor changes it may be adapted to mixed-phase operations wherein a portion of the reactor charge is injected as a liquid. Actually, a liquid injection nozzle is being designed and the charging of non-vaporizable material will be started very shortly. The liquid charge will be a cut from a vacuum tower fractionation of the tar separator bottoms.

The kiln is of the solid-bed type, similar basic design to larger units but is reduced in height to conform to a lower carbon burning load. It consists of seven alternate burning and cooling zones in which the amount of air for combustion, as well as the number of cooling coils in use for removal of heat, may be varied in order to carry out the regeneration of the spent catalyst under the most favorable conditions. Further simplification in kiln design has been made in that the fresh air for combustion and the outgoing flue gases enter and leave each zone on the same side of the kiln so that only one air inlet manifold and one flue gas outlet manifold are required.

A newly designed catalyst distributing device is

installed between the catalyst hopper and the kiln proper. Spent catalyst, introduced centrally into the distributor, flows into the first zone of the kiln through 16 catalyst feed pipes. The feed pipes are so designed that the upper ends, which are connected to the bottom head of the distributor, are arranged in a circular pattern while the lower ends, which extend into the kiln, are arranged in a square-pitch pattern covering the entire cross-sectional area of the kiln. This device contributes to uniformity in kiln operation by its control of particle size distribution in solid beds of catalyst.

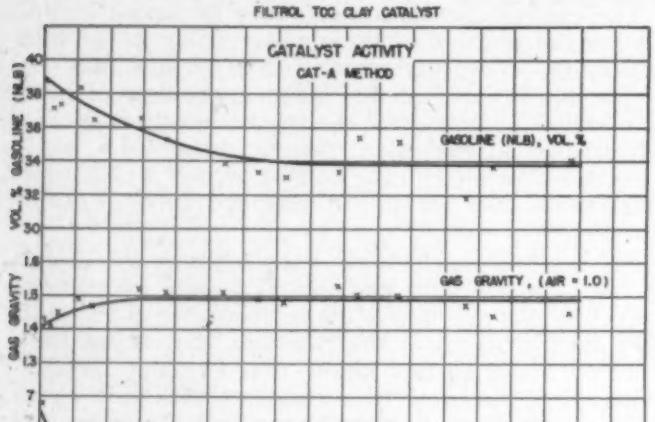


FIGURE 2

Catalyst Activity and Make-Up Data Versus Days on Stream

On the Leonard kiln the exhausting of the flue gases directly to the atmosphere from the main flue gas manifold has resulted in appreciable savings in equipment. In the units erected during the war, cyclone separators were installed in the flue gas stack above the regenerating kiln as a precautionary measure in order to collect particles of catalyst that may have been carried out of the kiln by the outgoing flue gases.

On former units the elutriator, which is the device used to maintain a satisfactory average catalyst particle size in the system by means of air classification, was also located in the flue gas stack above the kiln in order to utilize the flue gas cyclones to collect the elutriated "fines". A small portion of the regenerated catalyst stream was continuously fed into the top of the elutriator and contacted in a countercurrent manner with a portion of the outgoing flue gases; the small catalyst particles were carried out of the elutriator into the cyclones by the flue gas stream while the large catalyst particles flowed by gravity into the center of the kiln hopper immediately below. Since, however, the cyclones are not used in the main flue gas outlet stream, the elutriator on the Leonard unit has been installed at a lower elevation and made independent of the kiln system. A small stream of fresh air from the blower is the source of classification air and a single small cyclone separator mounted atop the elutriator is sufficient to collect all of the "fines" produced. Also, the large particles of catalyst from the bottom of the elutriator flow into the kiln main outlet catalyst line. This modification has served to increase the kiln coke-burning capacity by eliminating the return of several tons per hour of regenerated catalyst to the kiln.

As previously indicated, the circulation of catalyst is accomplished with a single, split-bucket type elevator in contrast to the older TCC units which were equipped with separate elevators for the spent and regenerated catalyst streams. Several other improvements in elevator design have also been incorporated. For example, the entire elevator mechanism, including the cylindrical housing, is suspended from the top of the structure of the unit proper, whereas, in the older units the elevator load was carried by its own supporting framework. The insulation of the housing has been simplified by replacing the formerly-used internal insulating panels with exterior insulation consisting of conventional, field-applied material. The pivoted or "walking" beam at the base of the elevator in which the foot-shaft is mounted is also totally enclosed in the housing.

Another novel arrangement in the processing plan of the Leonard catalytic plant is the utilization of a barometric-type, direct-contact condenser in the synthetic crude tower overhead stream rather than shell and tube condensers which are usually employed in this service. The advantages of decreased pressure drop and low maintenance cost afforded by the barometric-type of condenser are noteworthy. For example, with a shell and tube condenser in use on the Leonard unit, the tar separator would have operated at approximately 10 PSIG in contrast to the 6 to 7 PSIG pressure resulting from the use of the barometric condenser. The lower tar separator pressure is of importance since it permits the production of a greater percentage of tar separator overhead material or reactor charge at the same transfer line temperature. The synthetic crude tower overhead vapors enter the base of the barometric condenser wherein the heavier hydrocarbon components are condensed by a down-flowing stream of cooling water and pass into the gas and water separator tank on which the barometric is mounted. The non-condensable portion of the synthetic crude tower overhead stream passes up through the barometric and enters the top of the gas and water separator from which the gas compressors take suction. At the designed reactor charge rate and with a 75° F. inlet water temperature, a cooling water supply of approximately 1250 gallons per minute is required to condense and cool the synthetic crude tower overhead stream to 100° F. The rate of flow of effluent water from the separator tank is automatically regulated by a liquid level controller which is sensitive to the location of the gasoline and water interface in the quiescent section of the separator.

Operation of the Unit

During the first three months of operation of the unit, from March 18 to June 18, 1947, the plant had an on-stream efficiency of 95.8 percent. Of the total down-time of 92.3 hours, only 19 hours were attributable to the catalytic section. Moreover, of the 19 hours only 2.3 were due to interruptions in catalyst flow, the remaining 16.7 hours having been consumed in replacing bearings in the kiln circulating water

pump. On three occasions failure of the supply of electrical power to the refinery caused temporary off-stream periods amounting to 25.3 hours. In all such instances, however, the unit was promptly put back into operation as soon as stable power supply was restored. Also, 48 hours of down-time occurred between May 28 and 30, 1947, when the unit was purposely taken off stream to clean the stabilizer column in the gas plant. At the conclusion of the operation of the thermal cracking unit the stabilizer column had been performing satisfactorily at a production of 800 barrels per day of thermal gasoline. Because of the desire to tie-in the catalytic equipment and resume operations as quickly as possible, it was decided to defer an inspection of the column to a later date. However, the performance of the stabilizer at the higher rates of catalytic gasoline production, i.e., 1300 to 1500 barrels per day, indicated a definite lack of fractionating efficiency due to the fouled condition of the trays. A summary of the time efficiency of the plant is given in Table No. 1.

TABLE 1

Summary of TCC Unit Time Efficiency

9:30 P.M, March 18, 1947, to 9:30 P.M., June 18, 1947.

Hours on Stream	OFF STREAM TIME			On Stream Efficiency
	Hours	Percent of Total	Reason	
	2.3	2.5	Catalyst Circulation Interrupted.	
	16.7	18.1	Circulating Water Pump Bearings Replaced.	
	25.3	27.4	Refinery Power Failures.	
	48.0	52.0	Stabilizer Cleaned.	
Totals 2115.7	92.3	100.0		95.8%

In contrast to the constancy of the mechanical operation of the unit to date, a variety of charging stocks have been processed to fill the needs of the refinery. Although the unit was designed to process tar separator overhead material from reduced crude in a once through cracking operation, various deviations from the designed processing plan have been made. For example, straight run naphtha has been processed along with the tar separator overhead charge, both the light and heavy catalytic gasoil fractions have been recycled internally and for several days whole crude was charged to the vaporizing heater. All of these changes in charging stocks were made without interrupting the continuity of operation.

The charging of whole crude was a particularly advantageous procedure since it enabled the owner unit to continue production of marketable petroleum products during an emergency period when the crude unit in the refinery was forced off stream for repairs. Not only have many types of charging stock been processed in the reactor but also the charging rates have been varied over a considerable range for experimental purposes to determine the flexibility of the unit. For example, the recovery section of the plant was revamped to handle a daily production of approximately 1300 barrels of 10 pound motor gasoline, but the production of specification gasoline has actually been as high as 1900 barrels per day.

Typical Results

In Tables No. 2 through 4, summaries which are typical of the TCC unit operation on several of the charging stocks and processing schemes mentioned above are presented. These data were chosen at random from the daily log of the plant. Table No. 2 was prepared from the records of the operation on June 2 and 3, 1947, when the operating conditions and the charging stock were essentially equivalent to those for which the plant was designed. The 47 volume per cent yield of 10 pound motor gasoline having a clear CFR-M octane rating of 78 and a clear CFR-R rating of 89 is illustrative of a once through cracking operation on tar separator overhead from Michigan reduced crude. Actually, the octane ratings of the as-produced gasoline would have been higher had it been possible to exclude several percent of straight run naphtha overlap from the charge to the reactor. Due to limited crude fractionating facilities, the reduced crude produced at current crude throughputs contains three to four volumes percent of naphtha boiling within the 400° F. end point motor gasoline distillation range. This amount of overlap naphtha is equivalent to about 8 percent of the total gasoline produced.

Table No. 3 is typical of the recycle operations wherein approximately 1000 barrels per day of light catalytic gasoil plus about 2400 barrels per day of virgin tar separator overhead comprised the total reactor charge. As indicated, the conversion and product yields based on fresh charge to the reactor were correspondingly higher than those from the once through operation although the actual rates of production in barrels per day were lower, indicating the refractory nature of the catalytic cycle stock. Here again the octane ratings of the as-produced

TABLE 2

June 2 and 3, 1947 — Once Through Operation

Product Yields and Inspections

	ASTM DISTILLATION—°F.										OCTANES	
	BPSD	Vol. Percent	°API	IBP	10 Percent	50 Percent	90 Percent	EP	RVP	Weight Percent S.	CFR—M Clear	CFR-R Clear
Reed City Reduced Crude	3980		27.2	430	584	(32% @ 670° F.)						
Tar Separator Bottoms	895		19.4									
Reactor Charge	3085	100.0	31.1	284	555	690	(72% @ 711° F.)			0.64		
Stabilized 400° EP Motor Gasoline	1450	47.1	62.5	90	110	202	374	400	9.3	0.046	78	89
Light Catalytic Gas Oil	750	24.4	31.4	410	480	522	586	636		0.28		
Heavy Catalytic Gas Oil	432	14.1	22.2	516	636	684	752	760+		0.93		
Excess C_4 Fraction	328	10.6										
C_3 and Lighter	9.9 Weight Percent											
Carbon	5.0 Weight Percent											

Principal Operating Conditions

REACTOR

Tar Separator Oh'd Temp. ..... 818° F.
Reactor Catalyst Inlet Temp. ..... 1050° F.
Catalyst/Oil Ratio, V/V 3.9
Space Velocity, V/Hr/V 0.8
Reactor Inlet Pressure ..... 5 PSIG

KILN

290# Steam Production ..... 16,500 #/Hr.
Regeneration Air Rate ..... 9,500 CFM

gasoline were degraded by the presence of straight run naphtha.

Recycle Operation

Operations in which the heavy catalytic gasoil or synthetic crude tower bottoms fraction was recycled internally are illustrated by the summary given in Table No. 4. Although the recycling of this material is not generally advisable due to the high coke and low gasoline yields, at times it has been judicious to conduct such an operation in order to obtain products from the synthetic crude fractionating tower of certain boiling ranges. The most significant comment to be made about this operation is that, in spite of a sharp increase in coke production, there was no difficulty in continuing the smooth operation of the catalytic section or in removing the high coke deposit from the catalyst in the regenerating kiln. Incidentally, the recycling of catalytic gasoil or synthetic crude tower bottoms is an efficient means of augmenting the refinery steam supply. The production of steam in the kiln from the combustion of the coke deposit is accomplished at practically 100 percent heat utilization in contrast to a much lower fuel economy which would result from using the synthetic crude tower bottoms fraction as fuel in the refinery boiler plant.

During the period from April 22 to 25, 1947, raw, desalted Adams crude was charged to the vaporizing heaters and flashed in the tar separator to produce a tar separator bottoms fraction of 10° to 11° API gravity. The overhead from the tar separator flash, which contained all the straight run gasoline, naphtha and kerosene in the crude, was cracked in the reactor and processed in a conventional manner. A high yield of relatively low octane motor gasoline was produced due to the presence of the straight run gasoline in the charge. On the other hand, because of the desulfurization imparted to the straight run gasoline in the cracking operation, the lead susceptibility of the "as-produced" gasoline was very good, so that it was possible to prepare an acceptable gasoline product with the addition of 3cc TEL per gallon. The tar separator bottoms production from this operation was subsequently processed to marketable asphalt.

One of the factors which has contributed greatly to the maintenance of excellent product distribution from the operation of the plant is the high level of catalyst activity which it has been possible to maintain with catalyst make-up rates of the order of one ton per day. This is particularly significant in the

TABLE 3

May 6 and 7, 1947 — Recycling Light Catalytic Gas Oil

Product Yields and Inspections

				ASTM DISTILLATION —°F.						CFR-M OCTANES	
	BPSD	Vol. Percent	°API	IBP	10 Percent	50 Percent	90 Percent	EP	RVP	Clear	+3cc
Reed City Reduced Crude	2961		27.6	270	(3.7% @ 450° F.)						
Recycle	1020		32.8	442	472	494	540	584			
Total Heater Charge	3981										
Tar Separator Bottoms	533		15.2								
Total Reactor Charge	3448		31.6								
Virgin Reactor Charge	2428	100.0			(5.0% @ 450° F.)						
Stabilized 400° EP Motor Gasoline	1325	54.5	61.8	88	112	224	390	408	9.3	77	85
Light Catalytic Gas Oil	514	21.2	32.8	442	472	494	540	584			
Heavy Catalytic Gas Oil	257	10.6	19.0								
Excess C_4 Fraction	219	9.0									
C_3 and Lighter	6.8 Wt. Percent										

Principal Operating Conditions

REACTOR

Tar Separator Oh'd Temp.	820° F.
Reactor Catalyst Inlet Temp.	1010° F.
Recycle Ration, V/V	0.42
Catalyst/Oil Ratio, V/V	2.8
Space Velocity, V/Hr/V	0.9
Reactor Inlet Pressure	5 PSIG

KILN

290# Steam Production	18,000 #/Hr.
Regeneration Air Rate	11,000 CFM

TABLE 4

May 17, 18, 19 and 20 — Recycling Heavy Catalytic Gas Oil

Product Yields and Inspections

				ASTM DISTILLATION —°F.						CFR-M OCTANES	
	BPSD	Vol. Percent	°API	IBP	10 Percent	50 Percent	90 Percent	EP	RVP	Clear	+3cc
Adams Reduced Crude	3859		20.4	267	(5.3% @ 450° F.)						
Heavy Catalytic Recycle	773		22.8	478	574	618	702	714			
Total Heater Charge	4632										
Tar Separator Bottoms	1843		11.0								
Total Reactor Charge	2789		30.0		(6.0% @ 450° F.)						
Virgin Reactor Charge	2016	100.0									
Stabilized 400° EP Motor Gasoline	1030	51.1	63.7	84	108	206	372	402	8.7	78	85
Light Catalytic Gas Oil	494	24.5	31.6	358	460	480	524	560			
Heavy Catalytic Gas Oil	204	10.1	22.8	478	574	618	702	714			
xcess C_4 Fraction	167	8.3									
C_3 and Lighter	6.2 Wt. Percent										

Principal Operating Conditions

REACTOR

Tar Separator Oh'd Temp.	800° F.
Reactor Catalyst Inlet Temp.	102[illegible]° F.
Recycle Ratio V/V	0.38
Catalyst/Oil Ratio, V/V	3.6
Space Velocity, V/Hr/V	.67
Reactor Inlet Pressure	4.4 PSIG

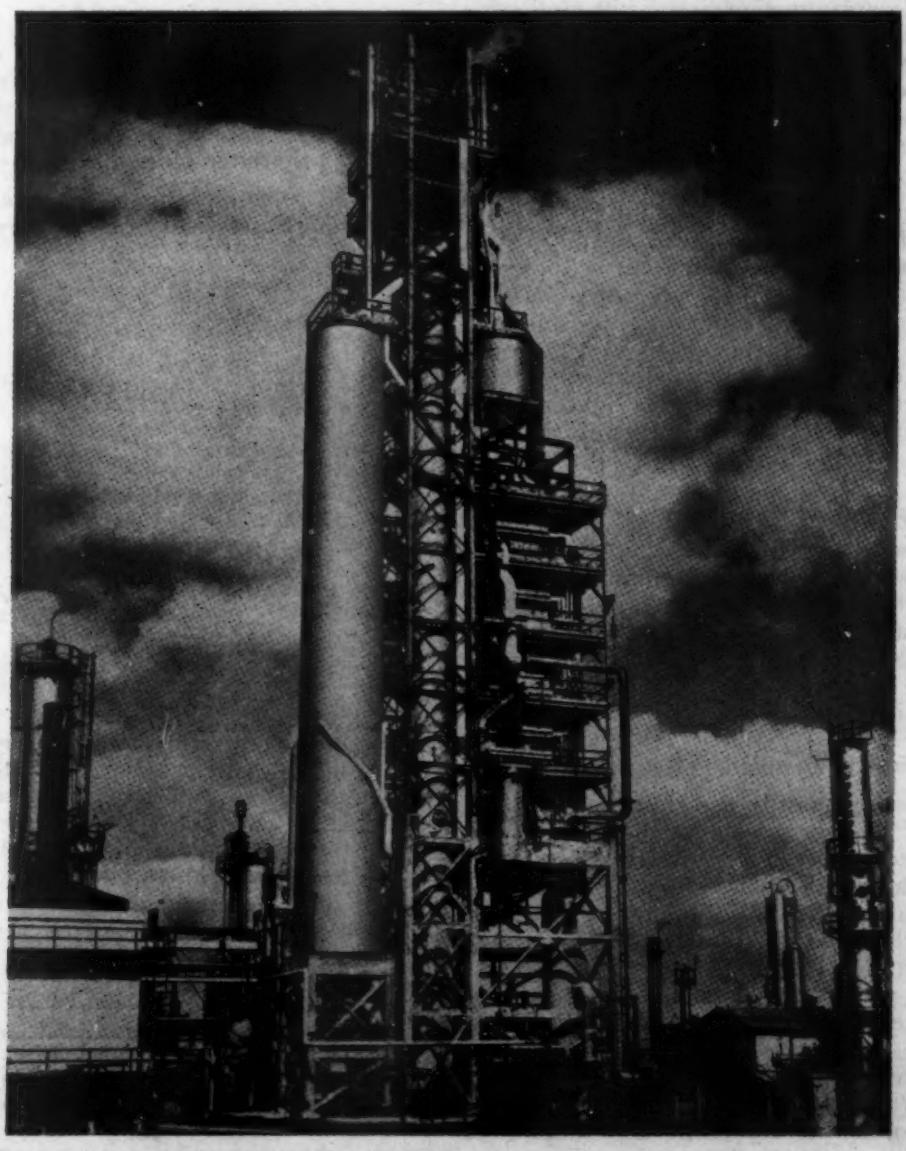
KILN

290# Steam Production	Over 20,000 #/Hr.
Regeneration Air Rate	11,500 CFM

operation of small catalytic cracking units where an excessive catalyst consumption could be a large portion of the operating cost. Figure 2 is a plot of the activity of the Filtrol natural clay catalyst in the system versus time and indicates that at the end of the first three months operation the catalyst in the system had an activity of 34 as measured by the CAT-A activity test. The very gradual decline in activity and the indicated equilibrium level of approximately 34 A.I. is shown by the graph. The graph also shows the daily catalyst make-up rates during the first three months of operation. Although the reactor charge rates have been consistently increased during this period, the consumption of catalyst has continuously decreased indicating that the catalyst make-up rate is independent of the reactor charge rate. It should be mentioned that no catalyst has been withdrawn from the unit and replaced with fresh catalyst for the purpose of maintaining or increasing the average catalyst activity. The catalyst make-up to date has been only that required to replace "fines" elutriated from the system and to compensate for normal catalyst shrinkage.

A significant factor affecting the economics of catalytic cracking for the small refiner is the efficiency with which the catalytic cracking equipment can be built and tied in to existing facilities. When construction costs are high due to labor inefficiency or to delay in delivery of materials, the conversion of the refinery to catalytic cracking operations becomes costly. Also, if existing refinery processing units, for example, a thermal cracking unit and recovery system, must be shut down for an extended period in order to tie in the catalytic equipment, the refiner stands to lose considerable revenue during the transition period.

The first orders for material were placed in April, 1946, and actual construction work was started on September 10, 1946. In less than five months the unit proper was completed and another month was consumed in making the necessary revisions and tying in the existing auxiliary equipment. Despite adverse Michigan winter weather, the equipment met all requirements and was placed into full operation approximately six months after ground was broken and less than one year after the first order for material was placed. It is estimated that similar units could be constructed at a cost of $250 to $300 per daily barrel of reactor charge capacity.



Thermofor Catalytic Cracking Unit, Leonard Refineries, Inc., Alma, Mich.

Multi-Column Distillation Of Natural Gasoline

FRANK J. LOCKHART
Department of Chemical Engineering, University of Southern California

THE separation of natural gasoline into its various components by distillation has received much attention with respect to the design of individual columns, but little attention has been given to the possible sequences of distillation columns which may be used to produce three or more products. This paper presents economic comparisons of a number of possible process arrangements of distillation sections in present day natural gasoline plants. Emphasis is placed upon the sequences of deethanizing, depropanizing, deisobutanizing, and debutanizing of natural gasoline.

Product Quality

Calculations were made in all cases for the following product specifications: 1) Natural gasoline with 12-lb. RVP, containing approximately 1 percent butanes; 2) n-butane, containing 5 percent isobutane and 3 percent pentanes; 3) isobutane, containing 5 percent n-butane and 3 percent propane; 4) commercial propane, containing about 2 percent ethane and 2 percent butanes; 5) ethane and lighter, containing sufficient propane to obtain condensation for reflux at 450 psig and 100° F.

Estimating Procedure

Since this paper is concerned only with the comparison of different sequences of columns to obtain the same products, incremental costs are used instead of total costs. Equipment such as vapor lines, reflux lines, reflux drums, valves, instruments, and pumps which are common to all sequences are eliminated from consideration.

(1) Sizing of Distillation Columns

Process engineers generally use short-cut approximate methods of design for economic comparisons. The design procedure given here has been used for a number of years with satisfactory results. This procedure is recommended only for preliminary estimations, although some distillation columns have been designed on this basis (and operated successfully). The final process design should be made by more accurate methods.

The procedure recommended for estimating purposes includes the calculation of the minimum number of theoretical liquid-vapor contacts and the minimum reflux ratio, which represent the limiting or boundary conditions of actual operation. The minimum number of theoretical liquid-vapor contacts is calculated from the Underwood[10] or Fenske[5] equation:

$$N^*_m \log L = \log \left(\frac{{}^xLKD}{{}^xhKD} \cdot \frac{{}^xhKW}{{}^xLKW} \right) \quad (1)$$

where N^*_m = Minimum number of theoretical liquid-vapor contacts (includes reboiler and partial condenser if present)

L = average relative volatility of the light key component referred to the heavy key component.

${}^xLKD$, ${}^xLKW$ = mol fractions of the light key component in the overhead product and bottoms product, respectively.

${}^xhKD$, ${}^xhKW$ = mol fractions of the heavy key component in the overhead and bottom products, respectively.

The minimum reflux ratio required for the separation cannot be determined accurately for multicomponent mixtures by any short, simple method. The Underwood equation[10] is accurate for binary mixtures, but is conservative for multicomponent mixtures. Equation (2) applies when the feed is at its bubble point, being identical with the corresponding Underwood equation for binary mixtures.

$$R^*_m = \left(\frac{{}^xLKF + {}^xhKF}{L - 1} \right) \left(\frac{{}^{x*}LKD}{{}^xLKF} - L \frac{{}^xhKD}{{}^xhKF} \right) \quad (2)$$

where R^*_m = approximate minimum reflux ratio calculated by Equation (2) equals L_m^*/D.

${}^xLKF$, ${}^xhKF$ = mol fractions of light key and heavy key components, respectively, in the feed to the column.

All other symbols as defined in Equation (1).

The approximate minimum reflux ratio calculated

General conclusions for natural gasoline plants:

1. ***Removal of ethane and propane***
   - ***A. New plant—use direct series***
   - ***B. Addition to plant with existing depropanizer — use inverted series, if ethane content is not too high.***
2. ***Removal of Iso-butane and normal butane (new plant or addition to existing plant).***
   - ***A. Use direct series (optional).***
   - ***B. If gasoline recycle to still is large, use inverter series.***

This paper was presented before the California Natural Gasoline Association, May 1, 1947.

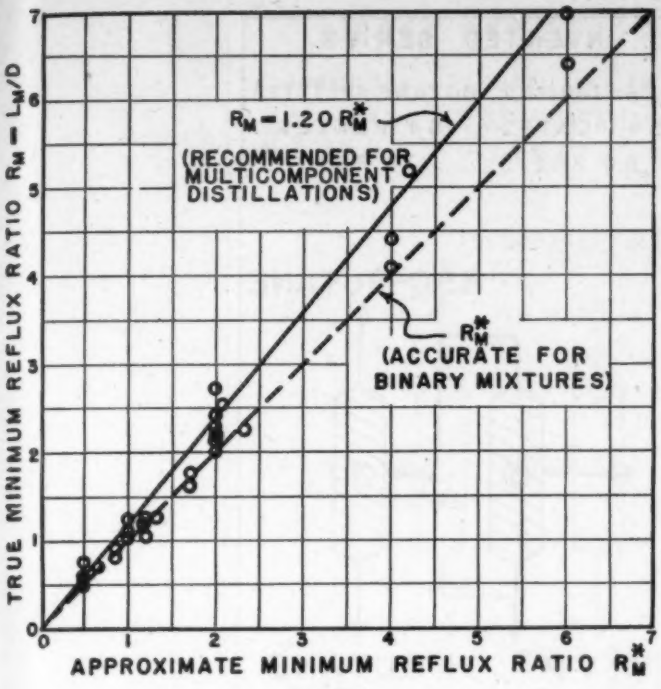


FIGURE 1

Accuracy of Minimum Reflux Calculation Recommended for Estimating Purposes.

from Equation (2) is compared with the true minimum reflux ratio in Figure 1, the points shown being for multicomponent distillations reported in the literature.[2,3,6] It is recommended that for estimating purposes, the value of the minimum reflux ratio be taken as 1.2 times the value of R^*_m calculated by Equation (2) for multicomponent distillations. It should be emphasized that this procedure gives a value of minimum reflux ratio accurate to about 15 percent only when the feed to the column is at or near its bubble point.

The relationship between the actual reflux ratio and the number of theoretical liquid-vapor contacts required for the separation is given in Figure 2. This relationship is a simplified form of the Brown and Martin[2] and the Gilliland[7] correlations, and is accurate for most cases encountered in industry (the feed at or near its bubble point, the minimum reflux ratio between 0.5 and 15, and the minimum number of theoretical liquid-vapor contacts between 6 and 50). It is recommended that for design purposes the actual reflux ratio be taken as 1.25 times the minimum reflux ratio, because this point corresponds with the economically optimum operation of most hydrocarbon distillation columns.

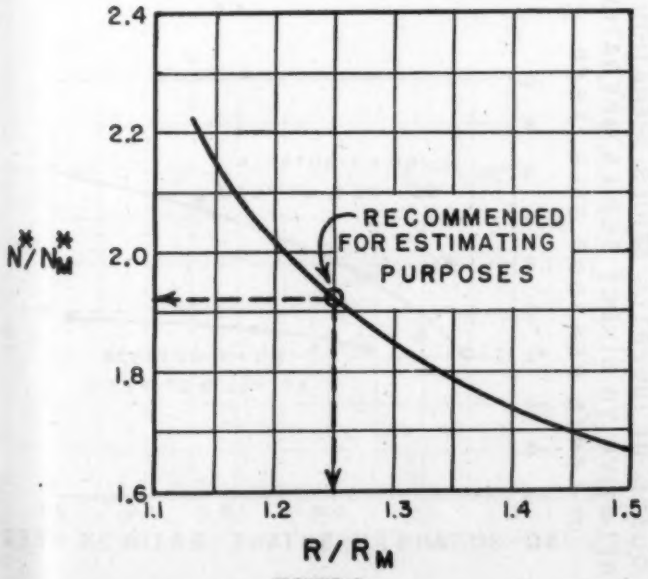


FIGURE 2

Relationship Between Actual Reflux Ratio and Number of Theoretical Liquid-Vapor Equilibrium Contacts.

Over-all plate efficiencies, used to convert the number of theoretical liquid-vapor contacts to the number of actual bubble-cap plates, may be obtained conveniently from the correlation of Drickamer and Bradford[4] or that of O'Connell.[8]

Plate spacings of 25-inch were used in all calculations in this paper. Column diameters were estimated by the correlation of Souders & Brown[9] as modified by Brown and Lockhart,[1] and rounded to the next larger half-foot.

Design pressures were considered as 50 psi higher than operating pressure. Deethanizers were limited to 450 psig operating pressure in all cases.

(2) Sizing of Extraneous Equipment

Heat exchanger loads were determined by conventional heat balances. All product and reflux streams were cooled to 100° F., while cooling water in all cases had an allowable temperature rise of 30° F. The reboilers for columns used 150-pound steam, with the control valves in the steam line 70 percent opened in all cases, except those specifically mentioned later.

The only pumps considered in this study were those required to transfer feeds to columns from lower-pressure accumulators.

(3) Cost Analyses

Fixed charges (depreciation, maintenance, etc.), were taken as 20 percent per year of the initial investment costs, which include the costs of columns, heat exchangers, and pumps on an incremental basis. The cost of columns, erected in the Los Angeles area and complete with insulation, ladders, and platforms, was taken as 20 cents per pound, total weight, a figure in agreement with turnkey estimates made in 1946. The costs of heat exchangers varied from $4 to $8 per square foot transfer area, installed basis, in accordance with 1946 quotations. The cost of pumps and drivers were also in accordance with 1946 estimates, installed with connecting piping.

Operating charges were based on the following unit cost figures:

150 pounds steam.....20 cents/M pounds.
Cooling water .....0.5 cents/M gallons.
Power .....0.5 cents/KW Hour.
Fuel .....15 cents/MM BTU.

(4) Scope of the Calculations

Production of the five streams specified previously requires four distillation columns in most instances. It is possible to arrange these four columns in at least fourteen different sequences. An attempt has been made to simplify the comparisons of different sequences by considering a number of separations requiring two columns for three products. Specifically, the following cases were investigated: a) Separation of depropanized gasoline into isobutane, n-butane, and 12-pound RVP gasoline; b) separation of de-

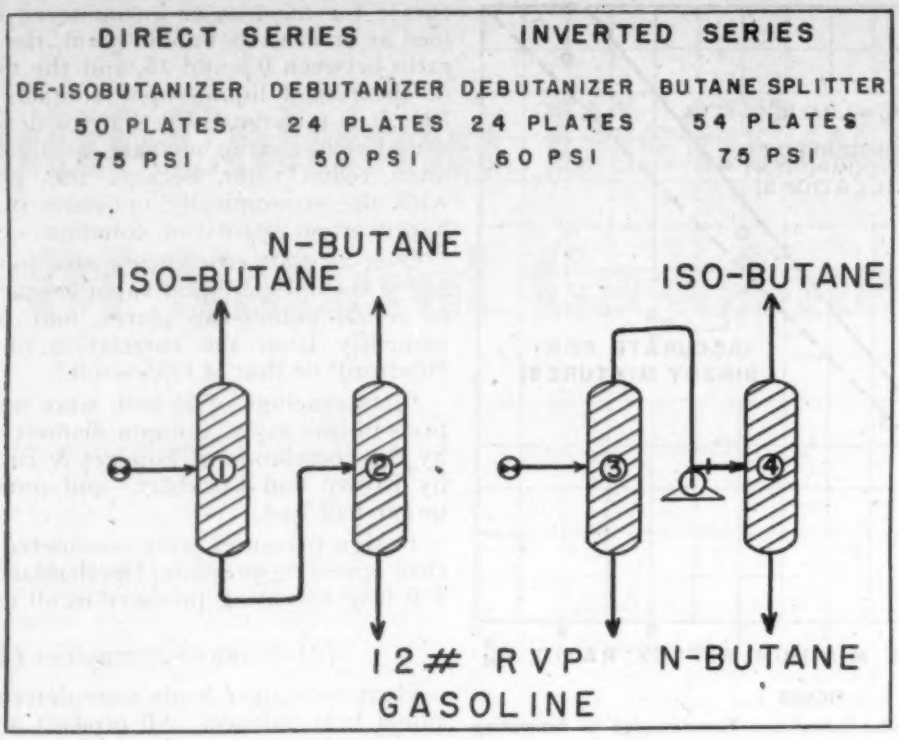


FIGURE 3
Sequences of De-isobutanizing and Debutanizing Natural Gasoline.

ethanized gasoline into propane, isobutane, and de-isobutanized gasoline; c) separation of raw natural gasoline into ethane and lighter, propane, and depropanized gasoline. Results of the study are presented in that order.

De-isobutanizing and Debutanizing Gasoline

After propane and lighter constituents have been removed, two distillation columns are required to produce isobutane, n-butane, and 12-pound RVP gasoline. The columns may be placed in either the so-called "direct" series or the "inverted" series as indicated in Figure 3. These two sequences have been compared for the feed compositions and rates indicated in Table 1.

TABLE 1
Feed Stocks Corresponding with Figures 3 and 4

	Feed A	Feed B
Rate, Gallons per Hour	2200.	4100.
Composition, Volume, Percent:		
Propane	0.4	0.2
Isobutane—n-Butane	56.5	30.3
Isopentane	16.9	27.2
n-Pentane	8.8	14.2
Heavier	17.4	28.1
	100.0	100.0

The feed rates listed in Table 1 were selected so that all column-diameters would be at least two feet. Feed B is a heavier stock than Feed A; it also represents the total feed where Feed A is the net feed and two volumes of gasoline are recycled to the still per volume of net gasoline product.

Results of this study are shown in Figure 4. It is to be noted that the costs given in Figure 4 represent the differences between the costs of operation of the inverted series and the direct series for the same feed and products. The ratio of isobutane to n-butane in the feed is ordinarily between 0.2 and 0.7 for natural gasoline stocks but the curves were extended to a ratio of 2/1 to include many refinery operations.

The inverted series compared with the direct series has in general higher fixed charges, principally due to the feed pumps required for the second column, and a lower operating cost, principally due to the reduction in steam consumption. It is interesting to note that the reflux rates are about 10 percent lower for the inverted series operations.

The following conclusions may be applied to new plants and also to existing plants in which the addition of a new column is planned to separate mixed butane into isobutane and n-butane:

1) If the isobutane concentration in the depro-

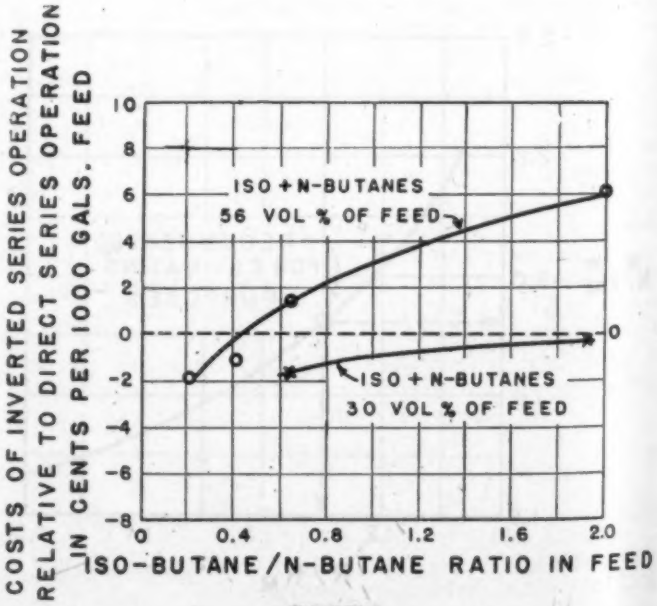


FIGURE 4
Costs of Inverted Series Relative to Direct Series for Production of Iso-Butane, N-Butane, and 12-Pound RVP Gasoline.

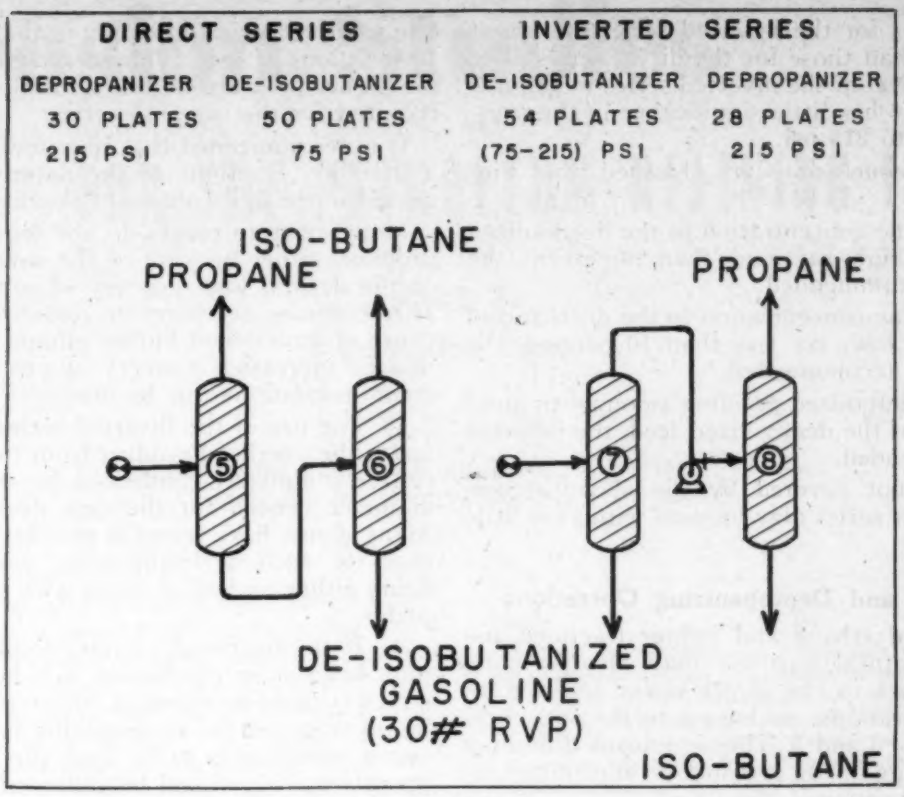


FIGURE 5
Sequences of Depropanizing and De-isobutanizing Operations.

panized gasoline is relatively high, say more than 30 volume percent, as in some refinery operations, the direct series is preferred.

2) If the isobutane concentration in the depropanized gasoline is relatively low, say less than 15 volume percent, the inverted series is preferred.

3) If the gasoline concentration in the depropanized gasoline is relatively high, say more than 70 volume percent, the inverted series is preferred.

4) For cases not covered by the first three conclusions, either series may be used without undue loss. The optimum sequence must be determined for each individual problem, and will depend upon such factors as the specific feed rate, the sizing of equipment, and the unit cost figures.

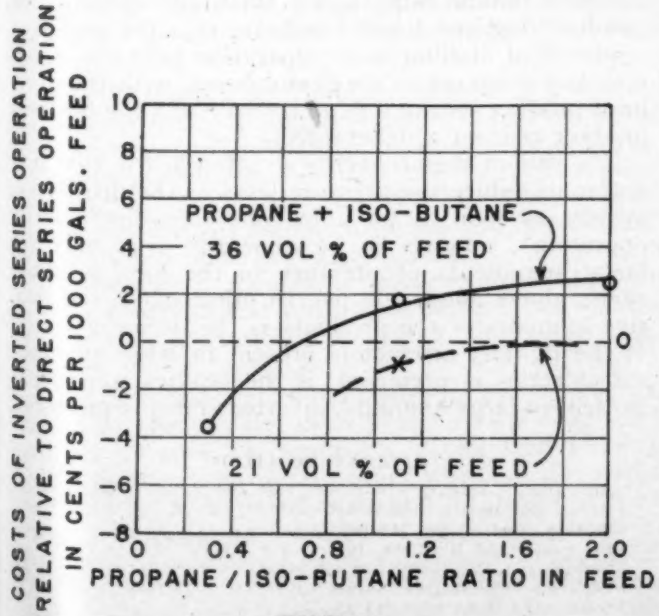


FIGURE 6
Costs of Inverted Series Relative to Direct Series for Production of Propane, Iso-Butane, and De-Butanized Gasoline (30-pound RVP).

Depropanizing and De-isobutanizing Operations

The separation of the deethanized feed into propane, isobutane, and de-isobutanized gasoline may be accomplished by either a direct series or inverted series as shown in Figure 5. These two sequences have been compared for the feed compositions and rates given in Table 2.

TABLE 2
Feed Stocks Corresponding with Figures 5 and 6

	Feed C	Feed D
Rate, Gallons per Hour	2570.	4500.
Composition, Volume, Percent:		
Ethane	0.4	0.2
Propane—Isobutane	36.3	21.5
n-Butane	28.0	16.9
Isopentane	13.8	23.3
n-Pentane	7.2	12.8
Heavier	14.3	25.3
	100.0	100.0

The feed rates listed in Table 2 were selected so that all column-diameters would be at least two feet. Feed C and Feed D of Table 2 correspond to Feeds A and B of Table 1. Feed D represents the total feed to the depropanizer where Feed C is the net feed and two volumes of 12-pound RVP gasoline are recycled to the still per volume of net gasoline product.

Figure 6 shows the results of this comparison and is similar to Figure 4. The ratio of propane to isobutane in the feed is ordinarily greater than 1.0 for natural gasolines, but the curves were extended to a ratio of 0.3/1 to include many refinery operations. The inverted series compared with the direct series has in general higher fixed charges and lower operating

costs. Reflux rates for the inverted series are about 5 percent lower than those for the direct series. The higher pressure-level of the inverted series in Figures 5 and 6 apparently has little significance in the pressure range of 50 to 215 psi.

The following conclusions are obtained from Figure 6:

1) If the propane concentration in the deethanized feed is relatively high, say more than 20 percent, the direct series is recommended.

2) If the propane concentration in the deethanized feed is relatively low, say less than 10 percent, the inverted series is recommended.

3) If the deisobutanized gasoline amounts to more than 80 percent of the deethanized feed, the inverted series is recommended.

4) For cases not covered by the above recommendations, either series may be used with very little difference in cost.

Deethanizing and Depropanizing Operations

The removal of ethane and lighter fractions and propane from natural gasoline may also be compared with respect to the direct series and the inverted series operations, analogous to the sequences shown in Figures 3 and 5. The significant difference is the large change in the pressure-level of direct series and inverted series of this case.

The comparison of the direct-and inverted-series for deethanization and depropanization is limited to a comparatively small range of ethane/propane ratios in the feed because of external factors which are not present in the previous comparisons. If the ethane/propane ratio is greater than approximately 0.6/1, the large amount of ethane and the accompanying methane makes it impossible to obtain complete condensation of 100° F. and 450 psig of the overhead product of the first column in the inverted series. A compressor must be used to feed the second column in the inverted series. The qualitative comparison given in Table 3 indicates that the direct series is preferred from an economic viewpoint.

TABLE 3

Ethane/Propane Ratio in Feed Greater Than 0.6

	Direct Series	Inverted Series
Operating Pressure, psi	(1) 450, (2) 215	(1) 450, (2) 450
Compressors	None	One
Heat Supply Required for Reboilers	(1) 150 lb. steam	(1) 400 lb. steam or fired reboiler
	(2) 150 lb. steam	(2) 150 lb. steam

On the other hand, if the ratio of ethane/propane in the feed is less than 0.25/1, as is the condition where deethanization of rich oil is employed in the absorping-stripping cycle,[11] it is possible to withdraw commercial propane as a sidestream from the deethanizer. This is due to the high volatility of ethane referred to propane (about 2.5/1). The one column operation, withdrawing propane as a sidestream, requires a fired reboiler or about 400-pound steam, but this is more than compensated for by the saving of one distillation column and its auxiliary equipment.

It is believed necessary to compare the inverted series with the direct series only when the ethane/propane ratio in the feed is between 0.25 and 0.60. One actual comparison at the ratio of ethane/propane —0.32 (ethane plus propane being 23 percent of the feed) indicates that the cost of inverted series relative to direct series operation is about + 40 cents per 1000 gallons of feed. This incremental cost is due to the higher pressure column and the additional pumps required for the inverted series.

It is recommended that in a new plant, the ethane and lighter fractions of the natural gasoline be removed in the first column of the distillation series.

Many existing plants do not separate ethane from propane, either because of the small ethane content or the desired low recovery of commercial propane. If it becomes necessary to install a deethanizer because of anticipated higher ethane concentrations or desired increased recovery of propane, two general recommendations can be made.

1) The use of the inverted series is more economical if the overhead product from the existing column can be completely condensed, because of the smaller diameter needed for the new deethanizing column. Many plants have found it possible to use sections of pipe for such a deethanizing operation, the pipes being either packed or fitted with piston-type bubble plates.

2) If the overhead product from the existing column can not be condensed, it is believed that direct series is more economical, although this case should be investigated for each specific separation. If direct series operation is to be used, the new column must operate at 450 psi and be sufficiently large to handle the large liquid load. If inverted series be used, compressors are required to feed the second column, and the new column must operate at 450 psi but will have a smaller diameter because of the smaller liquid load.

Summary and Conclusions.

The over-all operation of distillation sections containing three or four columns may be considered by combining the "unit" studies made above. General conclusions for typical natural gasoline plants are inclosed.

Conclusions reached in the unit studies also apply to many refinery operations. For example, the feed to the distillation section of a typical butane-alkylation unit has a low propane/isobutane ratio, a high isobutane/n-butane ratio, and a small concentration of gasoline. Figures 4 and 6 indicate that the preferred sequence of distillation is separation between isobutane and n-butane in the first column, with the overhead product sent to a depropanizer, and the bottoms product sent to a debutanizer.

The rule-of-thumb saying so often heard, that it is better to reduce the pressure level of the distillation system as soon as possible (implying direct series operation), appears to be generally true only for large increments of pressure in the high pressure range above about 200 psi. In other cases, the relative amounts of the products is the deciding factor. If the lightest product is present in large amounts, direct series is preferred; if the heaviest product is present in large amounts, inverted series is preferred.

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Corrosion Studies

FOR THE PETROLEUM REFINING INDUSTRY

PART 3.

Corrosion Tests

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PHYSICAL properties are, as a rule, easily determined but to establish some value to the behavior of a material in various chemical media and under different conditions is far more difficult. Too often a corrosion problem is complicated by the influence of so many factors that it is difficult even to isolate the factor of greatest weight. An alloy may "test" well against certain media under certain controlled conditions and yet when applied to practical use under almost identical influences may prove worthless. The frequency of such results has led to many doubts concerning the value of laboratory tests in relation to the future, applied uses of the metal tested. Corrosion testing involves many controversial problems.

The desirability of predetermining the corrosion-resisting usefulness of metals and alloys has led to the importance of various corrosion tests. The tests, as described, may be actual plant tests, field tests, or accelerated tests. Metals or non-metals may be employed in a (hit-or-miss) fashion until a satisfactory metal is found, or they may be tested under conditions as nearly like the actual as possible. The general resistance of the material to certain corroding media may suggest its applicability to other corrosive media. Thus, it is better than a guess to employ a metal for salt solutions if it has been found resistant to several acid solutions.

The "trial-and-error" method of testing a material is without doubt the most sure and accurate method of determining the worth of a material of construction but in order to eliminate the waste, confusion, and cost of this method, so called "field tests" were developed. By this method one uses samples of different materials under service conditions for a period of days, weeks, or months to observe their behavior. This is a very logical and simple method, but because of the time element it too is not altogether satisfactory.

Having a material and knowing its general properties, why can one not determine its suitability for a certain purpose by means of accelerated tests in every corrosive media? In other words, if a material is found to be resistant to many acids and salt solutions, why can it not be used for a purpose where the corrosion is not likely to be so severe? This reasoning has led to a number of tests called "accelerated tests." These latter methods immediately found many followers and stimulated proponents of other accelerated tests.

THIS is the last section of a three-part study of corrosion in the petroleum refining industry. Earlier sections have appeared in Petroleum Refiner for June and July of this year.

Here Dr. Rohrman treats corrosion testing and corrosion prevention. The previous material has covered corrosion economics, basic corrosion theory, and corrosion factors. As stated in the earlier sections of this work, the serious economic losses occasioned in process units and petroleum-handling and storage facilities by corrosion of piping, equipment, and tankage are well known to operating engineers and maintenance men. The total is greater than the loss of materials and replacement, as other factors such as the loss of time and products, product contamination, and damages incurred by equipment failure, may far exceed specific corrosion losses.

Routine inspection and replacement, long the conventional answer to corrosion problems is to advantage supplemented by the more effective methods of protection such as more resistant materials of construction, water treatment, counter-electrolytic protection, and others. The problems are too complex to permit the application of "standard" solutions. Any really effective approach to the problem of lowering overall corrosion costs must be based on a thorough knowledge of the many factors involved.

It is believed that this work by Dr. Rohrman will be especially useful to plant men since it treats a very involved and complex subject in a manner intelligible to the non-specialist, and yet makes little concession in accuracy or completeness to attain this readibility.

Accelerated Corrosion Tests

The best known accelerated corrosion tests are:

1. Electromotive tests
2. Total immersion tests
3. Partial immersion tests
4. Salt and acid spray tests
5. Wet and dry tests
6. Color tests.

Since corrosion is an electrochemical phenomenon, electromotive tests attempt to measure the potential and current between the sample and solution or between the sample and noble metal, or to make the specimen act as anode under a specified potential for a definite time, after which the loss in weight is determined. Ostensibly, such tests should determine the corrodibility of a metal in a solution; actually, the application and interpretation of such tests are difficult for the inexperienced. It is not only common knowledge that a piece of metal in a corroding medium will show different solution potentials at different points on its surface but that these potentials

might also be of different signs. The potential relationship will give, of course, the tendency for the sample to go into the solution used and under ideal conditions. According to Faraday's law, the current will be the criterion of the amount of metal going into solution (taking into consideration any anodic gas evolution). Recent long-time electromotive tests as employed by Bell Telephone laboratories indicate that such tests are very trustworthy in predicting the value of a metal for an actual installation.

The various immersion tests, probably the simplest to perform, are yet the most difficult to interpret correctly. During the total immersion test the test pieces are completely immersed in the corroding medium selected. In the partial immersion tests, which is of wider application, the effect of oxygen at the medium-air line can be noted. This factor is of special importance in cases where equipment or material is partially submerged in corrosion media. The last of the immersion tests, the alternate wet and dry test, or the intermittent test as it is sometimes called, subjects the samples alternately to a total immersion and to a drying period.

Prior to the immersion tests, the samples are weighed, so that after the test a re-weighing gives a loss or gain of the sample. Often it is necessary to remove the corrosion products which have formed upon the test piece so as to determine the extent of the corrosion. The loss in weight is generally translated into terms of loss per unit area per unit time. Sometimes the density of the material also is taken into consideration, and the depth of penetration per unit time is determined. Conclusions from these last determinations generally are fallacious because corrosion rarely proceeds uniformly over the surface. Pits and holes are formed by local action, and a specimen which is assigned a corrosion life by this method will invariably fail sooner than its calculated life.

Probably as important as the quantitative conclusions are the qualitative conclusions. The appearance of stains, pits, and hydrogen evolution, the color of the corroding medium, and the formation of corrosion products, all are criteria of the corrosion reaction. Recent practice has demanded that after the exposure a physical strain will be imposed upon the metal so that any change in physical properties can be noted. This test is especially important in cases where strain is likely to be a factor in the future use of the material. The extensive researches of McAdam of the U. S. Naval Experiment Station and McDonald of the Illinois Institute of Technology have been very enlightening on this subject.

In order to simulate tropical conditions a test called the "alternate hot and dry, cold and wet" test has been devised whereby the humidity and the temperature are varied between wide limits at regular cycles. Probably the most satisfactory accelerated tests are the salt and acid spray tests. The samples are subjected to a fine spray of salt or acid by means of an atomizer. Spray testers vary considerably in design, but they all have for purpose the formation of a fine mist which will come into contact with the test pieces.

The color tests depend upon the production, by the corrosion reaction, of chemical changes which can be detected by qualitative means. Chief among these is the ferricyanide or ferroxyl test. The most extensive use of this test is upon plated work; paper is dipped in a solution of NaCl and ferricyanide and applied to, say, the tin-plated iron. Where any porosity is present or the tin has corroded to the iron a blue spot will appear, indicating that the ferricyanide is reacting with the products of the iron corrosion.

Value of Accelerated Tests

Vernon in a simple manner summarized corrosion testing when he stated, "Corrodibility is not an intrinsic property of a given metal or alloy; it is to be regarded equally as a function of the particular corroding medium; it is also affected by various extraneous factors." Evans is just as logical when he states, "There is nothing essentially unsound in seeking for an accelerated test. But the acceleration must be obtained by intensifying the adverse factors which will be present under service conditions, not by introducing new factors." That these statements are correct has been amply proved by anyone familiar with the subject of corrosion testing.

The duration of the corrosion test is extremely important. Since time is a factor, the test should not be run over a period of too many days; on the other hand, too short a test might result in erroneous results. If the corrosion rate is low the time of exposure should be increased in order to produce reasonable data. If the corrosion is very rapid a small amount of solution may lose its original corroding power by becoming depleted. The nature of the corroding medium should remain as nearly constant as possible; a larger volume of solution is always more desirable than a smaller volume. Needless to say, the composition of the corroding medium and the conditions effecting it should be controlled very carefully. The presence of small amounts of impurities is often a very important factor in the corrosion of a metal. The corrosion of metal can be increased many times in acid media if as little as 0.10 percent ferric salts are present. Additions of traces of certain organic materials often effect the corrosion rate enormously.

In all cases, laboratory tests should specify and report as to size and surface area of the specimen tested, the metallurgy of fabricated states of the specimens, the volume of the solution, and the area of the solution exposed to air. The diffusion of oxygen is so important that samples will corrode at different rates in the same solutions if the volumes or surface areas of the media are different.

The effects of different oxygen concentrations upon the corrosion rates should be tried, if possible. When this is done the maximum intensified corrosion rate is obtained and the behavior of the metal toward various solutions can be conservatively determined. If the metal were merely placed in a solution for a definite period and a loss of weight determined, a conclusion might be obtained which would not necessarily follow under adverse conditions of oxygen concentration. Most alloys containing nickel are extremely sensitive to oxygen concentration. One can easily double and triple the corrosion rates of these alloys by choosing definite adverse oxygen concentrations. Iron or steel to be used for water pipes or outdoor uses often is given an accelerated test in an acid or salt solution. The results of these tests and of actual use generally are contradictory because of the difference in the conditions presented. In these tests any oxide film or rust will be affected by the solutions, while, in the air or water the oxide film may be protective to the elements.

Valuable information can be obtained by plotting the weight losses of a metal against variations in the

corroding medium. In this way one can plot loss in weight against changes of concentration, temperature, time of exposure, degree of circulation, etc. Plotted results have the advantages of acting as checks upon individual tests and of permitting interpolations.

There are two general errors to be guarded against when plotting and interpreting corrosion results. Figure 5 illustrates these errors. In Figure 5A three different loss points are plotted for the same specimens under the same conditions of test. A re-check might reveal the same data. It is obvious then that the specimens are exposed to a critical point where the slightest variations in variables cause grave changes in results. In Figure 5B the initial data may lead toward a smooth curve whereas more accurate data reveals a different trend.

In short, corrosion tests are relatively easy to perform but difficult to interpret. A corrosion value is rarely an absolute value .All tests should be reported under every factor possible and the adverse factors should be intensified so as to give "conservative" estimates as to the corrodibility of the material in question. Tests should run long enough to pass the period of induction. The qualitative aspects of the test, especially the physical tests, should be considered as well as the quantitative aspects.

If it is possible all test specimens should be given proper physical tests before and after exposure so as to establish any danger of physical deterioration. A specimen may withstand an accelerated test without any appreciable evidence of corrosion, whereas the physical test will reveal a decided drop in tensile strength or loss in creep strength.

Corrosion Prevention

"Save the surface and you save all" has correctly become a popular byword. Since corrosion reactions take place at the surfaces of metals and alloys, the protection of the surface is the prime objective in corrosion protection. Corrosion may be prevented or retarded by the use of the following methods:

1. Alloying
2. Removal of strains
3. Polishing
4. Producing insoluble oxide coatings
5. Producing insoluble phosphate coatings
6. Electroplating
7. Covering with metals other than by electroplating
8. Covering with non-metallic materials
9. Making cathodic with external electromotive force
10. Treatment of corroding media.

It can be seen that this group arranges itself into factors pertaining (1) directly to metal, (2) to the medium, and (3) to external influences. An account of each one of these methods could in itself make a thesis; in this manuscript a brief description must suffice.

1. *Alloying.* Not so long ago, the only common alloys were the brasses, bronzes, German silvers, and pewters. Today an enumeration of the iron alloys alone would run up into the hundreds. Alloys are not always devised for the purpose of corrosion resistance but also for improvement in physical properties. Alloying often improves chemical resistance as well as physical resistance.

Just why a particular alloy possesses such useful properties with respect to corrosion-resistance cannot be answered in this paper. With one group of alloys the resistance may be due to homogeneity, and with another to the ability to form passive films. On this phase of the topic many differing theories have been advanced.

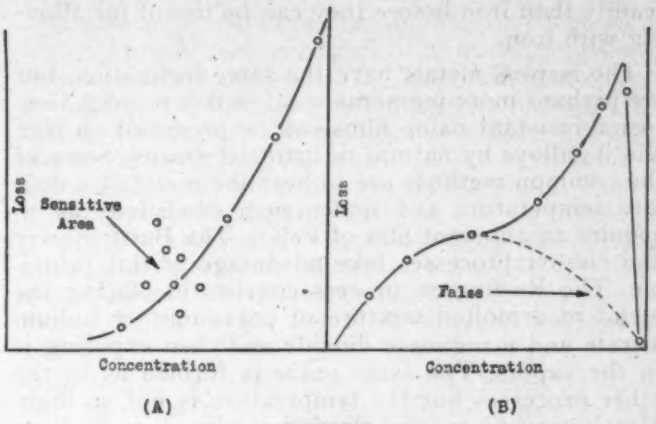


FIGURE 5

Small percentages of alloying agents may make great differences in the corrosion rate. A trace of a more noble metal with a low hydrogen overvoltage in zinc will cause rapid solution of this metal in most acid media. The presence of more noble metals with high hydrogen overvoltages have little effect on the corrosion rate. Additions of one or a few percents of alloying agents often have a great influence toward improving the corrosion resistance. Less than one percent tellurium in lead makes the latter much more resistant to sulfuric acid solutions. One percent of silver in lead makes it useful for anodes in the electrowinning of zinc. It so happens that alloying percentages from 11-20 percent have the greatest influence in promoting corrosion resistance. Chromium has much greater influence on the resistance of iron when present over 11 percent than when present at a lower percentage. Silicon imparts relatively little resistance to cast iron until 12 percent is present. Case after case may be cited to show that this range of percentages is an important one. Greater or lesser percentages than these rarely impart much corrosion resistance to the original metal.

2. *Removal of Strains.* As previously mentioned, strains offer focal points for corrosion reactions. A strained metal may be considered as an altogether different metal from the same metal in an unstrained condition as far as corrosion is considered. The strained portion always has a greater tendency to go into solution. These strains can be removed by heat treatment and annealing. Many manufacturers are resorting to this procedure to improve the corrosion-resistance of their fabricated materials.

3. *Polishing.* Any form of polishing which does not produce surface strains should make a metal more resistant to corrosion. A smooth surface will possess fewer crevices and indentations which might induce differential oxygen-concentration cells. Moreover, a smooth surface actually will have a smaller surface for the corroding medium to contact than will a rough surface. Industry has taken advantage of the value of polishing. Today most of the metal work that one comes in contact with, possesses a bright finish.

4. *Producing Insoluble Oxide Coatings.* It is perhaps fortunate that nature endowed the more anodic

metals with oxides which resist solution. Aluminum, chromium, nickel, and others form oxide films which tend to protect the underlying metal. It is characteristic of these metals, that they must oxidize more readily than iron before they can be useful for alloying with iron.

The ferrous metals have the same inclination, but are perhaps more temperamental in this respect. Corrosion-resistant oxide films can be produced on iron and its alloys by natural or artificial means. Some of the common methods are to heat the metal at a definite temperature and under such conditions as to acquire an adherent film of Fe_3O_4. The Barff, Bower and Gesner processes take advantage of this principle. The Ruffington process consists in placing the metal in a molten mixture of potassium or sodium nitrate and manganese dioxide and then exposing it to the vapors. The same oxide is formed as in the other processes but the temperature is not so high. Metals may be treated electrolytically so as to form insoluble oxide films. Bengough and Stuart made aluminum and aluminum alloys anodic in a chromic acid bath. Fink and Kenney used the same method in making "stainless" steels more resistant to corrosion. Under this same heading one may consider the effect of nitrogen, or nitriding. If iron containing aluminum is exposed to nascent nitrogen gas as obtained from the decomposition of ammonia at high temperatures, the surface of the metal hardens and becomes more resistant to mild corroding agents or oxidation.

5. *Producing Insoluble Phosphate Coatings.* Ferrous metals can be so treated with phosphoric acid and phosphates that insoluble iron phosphate films are formed. These compounds adhere to the iron surface and tend to protect the iron from further attack. This is the basis for the Coslett and Parker processes, which were mentioned previously. The latter process, now known as "Parkerization" or "Bonderizing," is used on the body-work of many well known automobiles. Not only does the phosphate coating protect the underlying metal but it also makes a good base for paints and lacquers.

6. *Electroplating.* Almost any metal can be electroplated with any other metal. A metal may be plated with one that is more electropositive or with one that is more electronegative. In the former case, iron may be plated with tin, silver, and gold, and in the latter case with zinc, nickel, and aluminum.

When metal is thoroughly covered with a more electropositive metal, it is protected from corrosion by virtue of the noble character of the electropositive metal. Examples of this are common silver-plated and gold-plated objects. Tungsten, tantalum, and the platinum metals also are used for plating less noble metals. The great disadvantage of noble-metal coverings becomes evident under conditions where the deposit is torn or scratched off, or when it fails to cover the surface properly. Any such condition causes local action currents to be set up if the more noble metal has a low hydrogen overvoltage, and the underlying metal corrodes much faster than if it had not been plated at all. Elimination of "pin holes" due to improper deposition is a problem constantly facing the electroplater. Tin plate is very satisfactory as a protection for iron and other anodic metals. Tin itself though more electropositive than iron is not a noble metal, but it forms an oxide film which is very resistant to corrosion. Cadmium-plated iron often is claimed to be very effective because of the low potential difference between cadmium and iron in weak electrolytes. Plating with less noble metal results in corrosion protection by another means. A zinc-plated iron is useful because when a break occurs only the zinc will corrode, so that at the expense of the zinc the iron is protected. Chromium-plated ware acts similarly. The art of electro-plating is complicated by the fact that many problems are encountered in making the deposits "pin-hole" proof, adherent, resistant to shock, etc.

7. *Metallic Coverings Other Than Electrodeposited.* Protective metals may be applied to metals by means other than the electrochemical, as by dipping in the molten metal, spraying with the molten metal, and heating in the presence of metal or metallic oxide powders. When a clean metal is dipped in a molten bath of another metal it acquires a coat of metal. If the molten metal is zinc the process is known as galvanizing and the coated metal is known as galvanized ware. Tin also may be applied to metal in a like manner.

Schoop was the first to discover the metal-spraying process whereby a molten metal is sprayed upon an object so as to cover it uniformly with a thin coating. The convenience and ease with which this process lends itself to practical work makes it very valuable to industry. Zinc is generally the only metal so applied.

When a metal is heated in the presence of another metal there is a tendency toward surface alloy formation. This phenomenon is known to the metallurgist as cementation. (It should not be confused with electro-chemical cementation.) When the lower melting metal is in the powdered state and at higher temperature this tendency for surface alloy formation is increased. The use of powdered zinc to alloy with metals and form a zinc surface is known as "Sherardizing," after Sherard Cowper-Cowles, the first to apply this method. Recently silicon has been encouraged to coat iron by the application of this same principle. The iron articles are covered with sand and heated to high temperatures. In time a corrosion-resistant iron-silicon crust forms on the iron.

The same method is used to cover metals with aluminum, and results in better heat resistance. This process, called "Calorizing," is used for covering iron, steel, nickel, copper, and brass. When a chromium covering is obtained it is called "Chromizing." Boron, tin, tungsten, molybdenum, tantalum, and many other elements have been applied to metals by this process.

8. *Covering with Non-Metallic Materials.* The most ancient and some of the newest means of protecting metals involve the use of various organic and inorganic covering materials. The early Romans employed paints and asphalt for protecting iron work. Some of the more recent applications are the use of rubber-lined tanks and equipment for handling hydrochloric acid, enameled steel work for the preparation of certain pharmaceutical products, and the use of various new lacquers, paints, and plastic coatings. In this group also would be included glass, oils, tars, cements, concretes, etc. Some materials such as silica and bakelite, have such satisfactory physical properties that in many chemical operations they may be used directly in place of metallic materials.

9. *Making Cathodic with External Electromotive Forces.* The electromotive forces driving a corrosion reaction are very small, generally in the order of tenths of a volt. Through the application of an external electromotive force of a greater magnitude

and in the opposite direction, anodic elements naturally will become cathodic, and undesired corrosion can be eliminated. Mention already has been made of nickel pasteurizing tubes which were protected by inserting the less noble aluminum metal strips in the milk. Use of zinc slabs in oil-well pipes is another example. The actual use of electromotive forces applied, *in situ,* during service is sometimes employed. The "Cumberland Process" being a good example of an industrial patented method making use of this principle. A potential of 6 to 10 volts and of low amperage is forced from iron anodes to the metal to be protected. The success of this idea depends upon the even distribution of the current to that metal and upon the slow rate of anode disintegration.

Within the past few years considerable strides have been made on these means of cathodic protection. Zinc, aluminum, magnesium and external potentials are employed for protecting iron and steel work. When any of these three metals is employed the method is referred to as the sacrificial method, owing to the fact that the corroding medium diverts its action from iron to one of these metal which is used. Since these metals are reasonable in price and simple to employ, the sacrificial method has found great use in industry. The sacrificial metal must be replaced from time to time owing to corrosion consumption. In installations where access to the corrosion is difficult or impracticable to attain, the use of superimposed direct currents of a few volts and a low amperage finds a great use. Many pipe lines are protected by a system of such protective devices.

The protection of steel and iron from corrosion by liquid media by means of zinc, aluminum, magnesium, or any external electromotive force is accomplished by exposing the sacrificial metal or the anode of the reversing cell to the corroding medium and then making an electrical connection with the metal to be protected. The area of protection afforded is influenced by the potential attained between that area and the anodic element serving to protect. The use of either zinc, aluminum or magnesium offers problems of relative protection per unit area, cost, and several vagaries of installation. It can be seen that since one equivalent of metal will protect one equivalent of iron, that the weights of zinc, aluminum and magnesium required to protect one unit of iron are in the ratio of 65.38/2, 26.97/3, and 24.32/2, or 32.69, 8.99 and 12.16. Now when one considers the relative costs of these metals required to protect one unit of iron, these are in the ratios of $0.09, $0.15, and $0.20 per pound. Finally, one must consider the factors of fabrication and design costs, contamination dangers, and the many imponderables of suitability and adaptability. The permanence and freedom from replacements make the external-electromotive-force method attractive where any appreciable maintenance of the protective means would be a problem.

10. *Treatment of Corroding Medium.* The corroding medium may be so treated as to change its hydrogen-ion concentration, its conductivity, or its oxygen concentration, factors that are of fundamental importance in determining the influence which the medium shall have upon anodic metals. The hydrogen-ion concentration of water, though in the order of only 10^{-7} gram ions per liter, is yet sufficient to enable the hydrogen to displace many metals. By the addition of small amounts of soluble carbonates or hydroxides the hydrogen-ion concentration can be forced to such a low figure (the pH to a higher figure viz, 9 or 10) that the resulting hydrogen potential will be more negative than that of most metals; consequently the normal corrosion processes will not be able to manifest themselves.

Water almost always contains dissolved gases, of which oxygen and carbon dioxide have the greatest influences upon corrosion. The importance of oxygen as a depolarizer and as a metal oxidizer has been previously mentioned. The presence or absence of carbon dioxide is important, because it dissolves in water to decrease the pH (increase the hydrogen-ion concentration) thus making it more possible for hydrogen to displace the metals. Since the presence of these gases is so necessary for most corrosion reactions, means have been devised whereby they can be removed. These means are called de-activation and de-aeration.

De-activation most often is accomplished by allowing the water to come in contact with iron or steel scrap prior to admittance to the boilers so that the oxygen dissolved in the medium will be consumed by the mechanism of depolarization during the corrosion of these scrap materials rather than by the pipes or boilers later on.

De-aeration is the physical process for removing gases from water. Since most gases are less soluble in hot water than in cold, they can be removed by pre-heating the water in special tanks or holders called deaerators, or simply feed-water heaters. The usual method is to heat the feed water to the temperature necessary for expelling the oxygen and then scrub the small bubbles of gas out by passing in oxygen-free steam. The solubility of oxygen per 100 g. of H_2O is approximately .007 g. at 0° C. and .001 g. at 100° C. Although not all the oxygen is removed by heating; its influence is nevertheless considerably decreased. There are a very great number of industrial de-aerators, some of which treat millions of gallons of water per hour. Combinations of de-activator and de-aerator are in use also.

The use of inhibitors, in a practical way, is of recent origin. Materials which when added to corroding media in small amounts tend to restrain the solvent action of such media are called inhibitors. There are many kinds and classes of these materials. The action of some inhibitors is specific to some one metal and the action of others is extensive. The action of an inhibitor seems to be that of screening or covering the anodic or cathodic portion of a couple with a film so as to retard the flow of current.

Traces of chromates or dichromates retard the corrosion of many base metals. Antimony chloride diminishes the avidity of hydrochloric acid for iron or nickel. Organic base materials such as essential oils, alkalies, oils, nitrogen bases, cyclic amino compounds, glue, etc., are very effective inhibitors for most corroding media. Hexamethylenetetramine reduces the corrosivity of HCl and H_3PO_4 solution on aluminum. Most of the aforementioned materials act differently if they are in acid or basic mediums and if they are added as traces or appreciable percentages. The addition of certain organic materials to pickling baths so as to prevent over-pickling is comparatively well known. There seems to be a very great opportunity for research in this branch of corrosion prevention.

One of the more recently advocated inhibitors is sodium chrom glocosate which has many claims for ability to inhibit waters from their corrosion action.

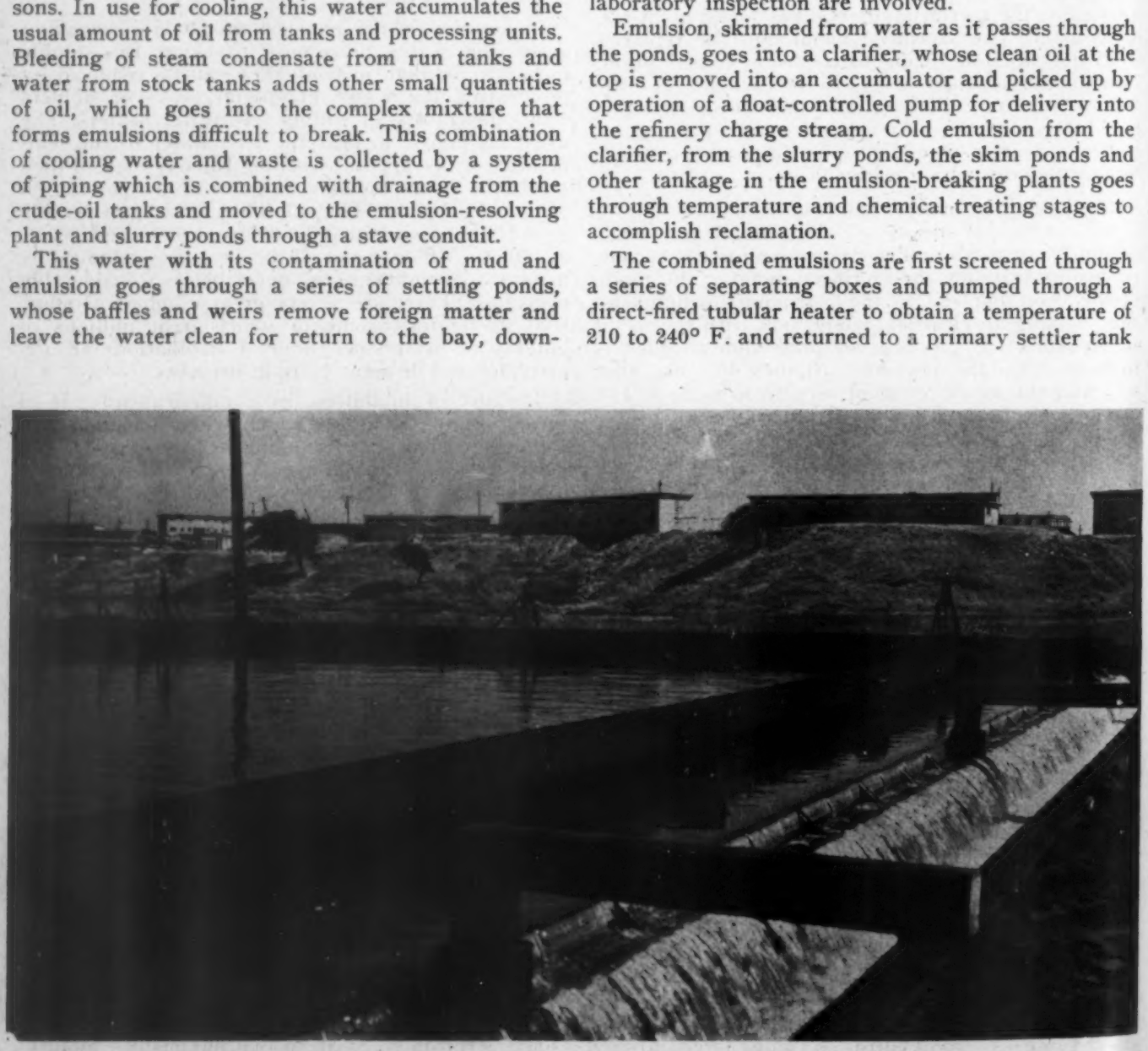
Water Settling and Emulsion Breaking System

FACED with the necessity of increasing the capacity of slurry ponds in waste treatment at its Oleum refinery, Union Oil Company of California has worked out a system which has simplified water clarification. Water is taken from the Sacramento River, upstream from the plant, and carries mud at all seasons. In use for cooling, this water accumulates the usual amount of oil from tanks and processing units. Bleeding of steam condensate from run tanks and water from stock tanks adds other small quantities of oil, which goes into the complex mixture that forms emulsions difficult to break. This combination of cooling water and waste is collected by a system of piping which is combined with drainage from the crude-oil tanks and moved to the emulsion-resolving plant and slurry ponds through a stave conduit.

This water with its contamination of mud and emulsion goes through a series of settling ponds, whose baffles and weirs remove foreign matter and leave the water clean for return to the bay, downstream from the plant. These ponds handle around 26,000 gallons per minute. Heavier particles settle out in the concentrator. Continued settling in the ponds and the weir of the last tank sends the water into the bay in better condition than when it entered the plant. Frequent visual inspections and regular laboratory inspection are involved.

Emulsion, skimmed from water as it passes through the ponds, goes into a clarifier, whose clean oil at the top is removed into an accumulator and picked up by operation of a float-controlled pump for delivery into the refinery charge stream. Cold emulsion from the clarifier, from the slurry ponds, the skim ponds and other tankage in the emulsion-breaking plants goes through temperature and chemical treating stages to accomplish reclamation.

The combined emulsions are first screened through a series of separating boxes and pumped through a direct-fired tubular heater to obtain a temperature of 210 to 240° F. and returned to a primary settler tank



Clear, clean water flowing from settling basin of Union Oil Company of California's emulsion resolving plant at Oleum, California

Stave pipe line which conveys cooling water from various units in the refinery to Union Oil's emulsion resolving plant at Oleum, California.

and held at 180 to 200° F. Some clean oil will break by normal separation and is removed by a swing line on the clean-oil pump suction, and placed in the clean-oil tank. Free water is withdrawn from the drain lines of the primary settler and pumped to surface water sumps and disposed of with the large amount of cooling water flowing constantly through the clarifier and separating vats. The free water withdrawn from the settling tank drops from the drain gate valve into an open trench beside the vessels so that the operator may, by visual inspection, determine when all free water has been withdrawn.

The emulsion between free water and the clean oil at the top is the material which requires specific treatment. It is pumped from the primary settler to a tank which when full is inspected in the laboratory. Representative samples are examined to determine the type of treatment required to break the emulsion. These emulsions vary widely and some are quite refractory. Such emulsions being complex yield little oil regardless of the type of treatment employed. Treatment is varied as to the tank of material. Pilot-plant testing indicates that a combination of sodium silicate and caustic soda in varying proportions usually is sufficient. When the type of treatment has been decided upon, the emulsion is pumped to the heater, and the treating material introduced with proportioning pumps. Heat from 220 to 240° F. is applied and frequently the tank is circulated through the heater, maintaining the temperature until the treating reagents have broken the emulsion.

The quantity of sodium silicate—caustic soda usually, but not always—is at the ratio of 40 percent by volume of sodium silicate, 10 percent caustic soda and 50 percent water. This reagent normally is employed on the basis of 3 percent of the volume of emulsion.

Other Treatment Different

Other emulsions, more complex in composition, and containing different materials, both as to oils and mud content, require different treatment. It has been found that caustic-neutralized sludges obtained from acid treatment of spray raffinates are effective in the treatment of some of the emulsions which do not respond to sodium silicate-caustic soda.

Neutralized sludge is used at a rate of from 1 to 2 percent of volume, depending upon the type of emulsion being treated. A combination of both the crude sulfonate and sodium silicate-caustic soda is required with some of the emulsions to obtain a satisfactory break.

The current rate of accumulation of emulsions is around 640 barrels per day, treated daily by the various types of reagents found most effective. Manifolding in the emulsion-breaking plant permit a variety of treatments in many different steps. Emulsion may be recirculated while being heated, reagents added while recirculating, or treated in a one-pass pumping from tank to tank. Free oil is not treated. Mud is not processed except that it is given ample time for separation, finally being deposited in storage ponds at the rate of 110 barrels per day.

The cost of treating the emulsion varies from batch to batch, arrived at by the amount of handling required and the quantity of treating reagents necessary to obtain an effective break.

Motor driven pumps which handle emulsion and water in the Oleum, Calif., emulsion resolving plant of Union Oil Company of California.

Heat Transfer Coefficients for Condensing Hydrocarbon Vapors

DANIEL A. DONOHUE
The Lummus Company

A SIMPLIFIED form of the Nusselt equation $h_m = C(L/w)^{1/3}$ is presented for calculating heat transfer coefficients for hydrocarbon vapors condensing on horizontal tubes. This simplification results from the observation that the term $0.955(k_f^3\rho_f^2g/\mu_f)^{1/3}$ in the Nusselt equation is approximately constant over the usual condensing temperature range for the hydrocarbons considered. Since solution requires that only the condensate loading w/L be known, the necessity for looking up values of the physical properties k_f, ρ_f, and μ_f at the pertinent film temperature is obviated; this results in an easy, direct, time-saving method. Application of this equation to commercial design is illustrated.

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THE theoretically derived Nusselt relations[6] for calculating the heat transfer coefficient of condensation on horizontal tubes are used for designing commercial condensers. The relations are in two forms; the first is in terms of temperature difference Δt:

$$h_m = 0.725\ (k_t^3\rho_t^2g\lambda/N\mu_t\ \Delta tD)^{1/4} \qquad (1)$$

and the second is in terms of condensate loading w/L:

$$h_m = 0.955\ (k_t^3\rho_t^2gL/\mu_t w)^{1/3} \qquad (2)$$

where D = outside tube diameter, feet
g = acceleration of gravity = 4.17×10^8 ft./hr.^{2}
h_m = mean value of the coefficient of heat transfer for the entire tube bundle, Btu/(hr.) (sq. ft.) (° F.)
k_t = thermal conductivity of condensate at average film temperature, Btu/(hr.) (sq. ft.) (°F.)/ft.
L = horizontal tube length, feet
N = number of tube rows in a vertical condensing stream
t_t = average film temp. = [condensing vapor temp. + (tube wall temp.)/2], ° F.
w = rate of flow of condensate from lowest point on condensing surface, lb./hr.
Δt = temperature difference between the dew point of the condensing vapor and the outer tube wall temperature, ° F.
λ = latent heat of condensation at saturation temperature, Btu/lb.
μ_t = viscosity of condensate at average film temperature, lb./(hr.) (ft.)
ρ_t = density of condensate at average film temperature, lb./cu. ft.

Several charts[1, 2, 7] essaying rapid solution of the above equations have been presented. However, it should be pointed out that charts devised to solve Equation 1, which require substitution of the value of temperature difference Δt, are not desirable for design use, because Δt is not readily known and must be determined by trial and error, and this necessitates more than one solution of the problem. On the other hand, Equation 2 requires substitution of the value for condensate loading w/L and, since this value is known at the outset, only one solution is necessary. Therefore Equation 2 is the relation suitable for condenser design.

Constant values for the term $0.955\ (k_t^3\rho_t^2g/\mu_t)^{1/3}$ were observed for hydrocarbons and for petroleum fractions over the usual condensing temperature range. For this commercially important case the heat transfer coefficient may be expressed as

$$h_m = C(L/w)^{1/3} \qquad (3)$$

wherein the constant C, which equals $0.955\ (k_t^3\rho_t^2g/\mu_t)^{1/3}$ is characteristic of the compound. Equation 3 is the simplest and most facile means of solution of the condensation equation yet developed, since the only required quantity is condensate loading w/L, which is immediately available, and search to obtain the values of the physical properties k_t, ρ_t, and μ_t at the appropriate film temperature is unnecessary. The superiority of Equation 3 as a ready means of calculating heat transfer coefficients for condensing hydrocarbons becomes apparent by comparison with the references listed.[1, 2, 7]

Constancy of Physical Properties

It was noted for pure hydrocarbons and for petroleum fractions that, as the result of the fortuitous combination of physical properties, the value of the term $0.955\ (k_t^3\rho_t^2g/\mu_t)^{1/3}$ remained constant within ±10 percent throughout the temperature range for each individual compound.

Table 1 lists calculated values of this term for the paraffin hydrocarbons shown throughout the indicated temperature range. Viscosity values from Drickamer and Bradford,[3] density values from Nelson,[4] and thermal conductivity values from Smith[8] were used; since measurements of thermal conductivities are available only over the range 68° to 212° F., values at other temperatures were obtained by extrapolation.

Table 2 lists calculated values of $0.955\ (k_t^3\rho_t^2g/\mu_t)^{1/3}$ for three typical petroleum fractions throughout the indicated temperature range. Viscosity values from Nelson,[5] density values from Nelson,[4] and thermal conductivity values from Smith[8] were used.

Simplified Condensation Equation

Referring to Equation 3, C represents the average value of $0.955\ (k_t^3\rho_t^2g/\mu_t)^{1/3}$ for each compound listed in Tables 1 and 2. The value of C for pentane and for

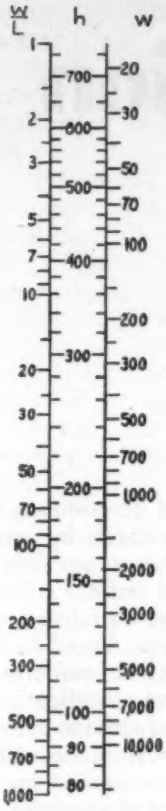

FIGURE 1

Condensation of Hydrocarbon Vapors on Horizontal Tube Banks

h = coefficient of heat transfer = Btu/(hr.) (sq. ft.) (°F.)
L = tube length, feet
W = maximum condensate flow in a vertical stream, lb./(hr.) (tube)

the 76.5° API natural gasoline is 775. For these compounds Equation 3 becomes

$$h_m = 775(L/w)^{1/3} \qquad (4)$$

A chart which may be used for solving this equation is given in Figure 1; to use it, w/L must be known, or, if L is 16 feet, only w need be known. Using Equation 4 or Figure 1 as a basis, heat transfer coefficients for the other compounds can be obtained by multiplying by the following factors:

VAPOR COMPN.	Chart Multiplier
C_5	1.0
C_6	0.95
C_8	0.93
C_{10}	0.87
C_{12}	0.86
C_{14}	0.83
Light gasoline	1.0
Gasoline	0.9
Kerosine	0.88

TABLE 1

Values of C in Equation 3

t_f	C_5	C_6	C_8	C_{10}	C_{12}	C_{14}
50	780	728	668	....	....	....
100	780	746	698	625	....	....
150	780	755	713	662	609	....
200	764	763	733	679	650	607
250	748	741	728	695	667	625
300	738	728	713	687	672	652
350	....	713	678	662	675	655
400	....	681	....	643	678	654
450	....	....	....	641	645	649
500	....	....	....	....	625	636

TABLE 2

Values of Constant for Three Typical Petroleum Fractions for Indicated Temperature Range

t_f	76.5° API Natural Gasoline	57° API Gasoline	42° API Kerosine
50	727	....	....
100	762	667	....
150	785	696	621
200	806	699	664
250	....	704	676
300	....	702	684
350	....	....	675
400	....	....	665
450	....	....	652
500	....	....	628

Adaptation to Design

An experimental investigation of a small tube bank[9] indicates the suitability of the Nusselt relation for design use. This relation is applicable only to streamline flow of condensate on the tubes, Reynolds number less than 2100; but on horizontal tubes condensate flow rarely exceeds this value. The Reynolds number for horizontal tubes is

$$N_{Re} = D_e G/\mu_f = 2w/\mu_f L \qquad (5)$$

where D_e = equivalent diameter of flow area, feet
G = mass velocity, lb./(hr.) (sq. ft.)
N_{Re} = Reynolds number

To determine w the total flow of condensate is divided by the number of vertical condensing streams. For the case of a tube bundle having a rectangular cross section, the number of vertical condensing streams would be equal to the number of tubes in a horizontal row if an "in line" tube spacing were used; if a staggered arrangement were used, it would be twice this number. In practice tube bundles of circular cross section are used; to resolve into a square bundle, the number of tubes at the horizontal diameter is multiplied by 0.886 when the pitch is in line and by 1.77 when staggered pitch is used.

For example, a shell-and-tube condenser was used to condense 43,000 pounds per hour of pentane vapor at 140° F. under an operating pressure of 15 psig. The unit used was a shell of 28-inch outside diameter having 580 ¾-inch outside diameter tubes on 15/16-inch triangular pitch, 16 feet long. The number of tubes at the horizontal diameter was 27, and the average number of vertical condensing streams was $1.77 \times 27 = 48$.

$w = 43{,}000/48 = 896$ and a value of $h_m = 203$ is read from Figure 1. The Reynolds number may be calculated from Equation 5

$$N_{Re} = 2w/\mu_f L = 2 \times 896/0.436 \times 16 = 258$$

which shows that the condensate was in streamline flow.

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Copper Strip Corrosion Tests

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THE corrosiveness of petroleum products as indicated by various copper strip corrosion tests is considered to be an important property of these products. Currently, maximum allowable corrosion limits, although not always clearly defined, are included in the specifications on motor and aviation gasolines, industrial naphthas, diesel fuels, domestic fuel oils, et cetera.

Studies have been carried out at the Whiting plant during the past two years on methods of sweetening or finishing distillate fuels and industrial naphthas with a view to meeting more rigid corrosion requirements. In the course of these studies two questions invariably came to the fore—namely, (1) what degree of corrosion can be tolerated as indicated by any given test method, and (2) what type or types of sulfur compounds are corrosive in the various tests?

The first question is complicated by the fact that the degree of corrosion as indicated by the appearance of the test strip is usually defined in rather vague terminology and further by the fact that the order of appearance of colors, which indicate the degree of corrosion, does not undergo a smooth progressive change from no discoloration to a darkened strip. As a result of this, purchasers of large amounts of industrial naphthas have classified naphthas of intermediate corrosiveness as unsatisfactory while accepting more corrosive stocks as satisfactory.

An answer to the second question—namely, what types of sulfur compounds are responsible for corrosion in the various tests—was desirable in order to determine what type of finishing procedure would be feasible or necessary in order to suppress or eliminate the type of sulfur compounds causing corrosion in any given test method.

IN THE course of determining the corrosiveness of various light oil products by current test procedures it was observed that copper strip corrosion manifests itself in a series of distinct colors so that the degree of corrosion can be correlated with the appearance or colors of the strips. Based on this observation, tentative sets of corrosion standards have been prepared for comparison and specification purposes. Work is in progress to establish permanent standards in which the color of the strips will not only correlate with the degree of corrosion but also will be a function of the amount of corrosive sulfur present.

Thus the author summarizes his report of the development work on the standardization of corrosion tests in a paper, which was presented before a joint meeting of technologists and operating personnel of Standard Oil Company (Indiana) and affiliated companies, French Lick, Indiana, May 5 through 9, 1947.

Corrosion Tests and Their Import

This paper presents a summary of the work done to date with a view to developing corrosion standards so that once the maximum allowable corrosion limit is established for a given product, the strip obtained on the product can be compared with the standards and rated either as passing or not passing. Also, some information is presented on the types of sulfur compounds which cause corrosion in the current test methods. Although the final results, when obtained, may be applicable to heavy oil products, the discussion is limited to tests and results on light oil products on which these initial studies are being made.

Major variables affecting the degree of corrosion in the various test methods are: (1) the amount of corrosive sulfur or sulfur compounds present, (2) the temperature at which the test is performed, and (3) the time of exposure of the copper strip in the test. In current corrosion test methods on light oil products the last two variables are fixed in order to determine the first. A summary of these tests is presented in Table 1.

TABLE 1
Current Test Methods on Light Petroleum Products

TEST METHOD	Strip Size	Temperature °F.	Exposure Time
ASTM D-130	0.5″ x 3″	122	3 Hours
ASTM D-484	0.5″ x 3″	212	3 Hours
ASTM D-235	0.5″ x 3″	B.P.*	30 Minutes
Philadelphia	0.25″ x 1.5″	Variable**	Variable**

* Slightly above the initial boiling point of product under test.
** Strip in flask during ASTM distillations.

The ASTM D-130 (3 hours at 122° F.) test is currently imposed on motor gasolines and to some extent on distillate fuels. Requirements are that no visible or appreciable change shall occur in the appearance of the strip. Passing this test presumably assures that no harmful corrosion of copper or copper alloys in automotive or burner fuel systems due to sulfur will occur.

More Drastic Test

The ASTM D-484 (3hours at 212° F.) test is much more drastic than the D-130 test. Currently it is imposed on Diesel fuels and is being considered as such, or with some modification in time of exposure, for use

on distillate fuels. For use on diesel fuels a perfect strip at the end of the test is not required by prominent manufacturers of diesel equipment. In connection with this test, therefore, the question arises as to interpretation of corrosiveness and degree of corrosion that can be tolerated.

The ASTM D-235 (30 minutes at boiling point) test may or may not be more severe than the D-484 test depending upon the initial boiling point of the product. It is imposed primarily, if not exclusively, on industrial naphthas. In most instances a perfect strip after exposure to the product is not required and therefore interpretation and tolerance are also of importance on strips obtained by this method. Passing this test presumably insures the user of the product that no darkening of light colored lead-base paints will occur in storage; that no localized corrosion ("pimpling") of metal surfaces will occur when used as a thinner in finishes applied to metal surfaces; or that no harmful corrosion will occur when such a product is used as a cleaning agent for metal surfaces.

Nature and Cause of Corrosion

The Philadelphia test (strip in flask during ASTM distillation) is the most drastic corrosion test shown in Table I. As originally proposed by the Philadelphia Paint and Varnish Club, stipulations were that the strip should show no black after exposure. It is imposed by some varnish manufacturers on naphthas used as the diluent in the hot open-kettle method of thinning resins in the process of varnish manufacture. No blackening in this test presumably indicates that the naphtha contains no sulfur which will react with the metals present—e.g., lead as lead resinate—in the varnish during its manufacture. However, some varnish manufacturers believe that naphthas which show a minimum amount of corrosion in this test are desirable in order to insure a minimum of darkening of clear varnishes.

In the course of making the foregoing tests on various refinery products it was observed that copper strip corrosion manifests itself in a series of rather distinctive colors and that, regardless of the type of stock or severity of the test, the color changes are invariably in the same order. For example, a strip which will turn black in the 3 hours at 212° F. test, will progressively undergo definite color changes. A freshly polished strip will pass through various shades of orange, red, lavender, silver or brassy, then multi-colored or peacock, and finally turn black. The relative corrosiveness of various stocks, using a given test method, can be estimated, therefore, by noting the color of the strip at the end of the test. This phenomenon of Progressive color changes naturally led to the idea of developing copper strip standards for comparison and classification as to degree of corrosion.

Sulphur Compounds

That corrosion, even a slight orange discoloration of the strip, is due to sulfur was confirmed by immersing the corroded strips in dilute hydrochloric acid and noting the evolution of hydrogen sulfide. Also, the addition of elemental sulfur or certain corrosive sulfur compounds to a non-corrosive distillate produced these same color phenomena—the color formed depending upon the amount of corrosive sulfur added and upon the severity of the test method.

The types of sulfur compounds which cause corrosion or color formation from orange to black in the various test methods are: elemental sulfur, hydrogen sulfide and polysulfides. Mercaptan, thiophenes, sulfides and disulfides are believed to be non-corrosive to copper unless sufficiently high temperatures are attained in the test procedure to decompose these types of compounds. An example of such decomposition occurs in the case of organic disulfides at temperatures above about 300° F. The decomposition of disulfides, formed from mercaptans on "sweetening" the higher boiling industrial naphthas, makes it particularly difficult to pass the Philadelphia test. The presence of as little as 0.008 percent sulfur as high boiling disulfides will cause blackening in this test.

The color of the strips obtained by any test method is believed to vary with the thickness of the copper sulfide film formed on the surface of the copper strip and is believed to be due to light interference phenomena.

Standardization of Corrosion Strips

The first method of preparing corrosion standards for classification or rating of products was an arbitrary one. Sets of standards were prepared by varying the time of exposure in a rather corrosive petroleum distillate at a temperature of 212° F. In so doing, the amount of corrosive sulfur was held constant in that the same stock was used and, obviously, the second major variable, temperature, was held constant at 212° F. The third major variable, time of exposure, was arbitrarily but successively increased for each strip and the test stopped when a distinct color change was observed from that of the previous strip. Sets of strips prepared in the above manner, or comparable strips, have been submitted to various departments and laboratories within our Company for tentative reference standards. These sets of standards, consisting of 13 strips, were numbered from zero to 12 and covered the entire range from no corrosion to black and scaly. The numbers and descriptions of these strips are presented in Table 2.

TABLE 2

Corrosion Number and Descriptive Terms for Standard Copper Corrosion Strips

Corrosion Number	Name
0	Perfect
1	Light Orange
2	Dark Orange
3	Claret Red
4	Lavender
5	Silvery Lavender or Silver
6	Brassy
7	Brassy Red
8	Peacock
9	Transparent Black
10	Graphite Black
11	Mat Black
12	Scaly Black

Obviously, the above method of producing sets of standard reference strips is not desirable because the time of exposure cannot be fixed as long as the amount of corrosive sulfur is not established. Furthermore, a more desirable method of preparing sets of standards is to fix the time of exposure and vary the amount of corrosive sulfur to be added to a non-corrosive product. To accomplish this objective, considerable effort has been put forth (1) to find a suitable corrosive sulfur compound which can be added in incremental amounts to an originally non-corrosive stock or solvent, (2) to find such a standard non-

corrosive solvent and (3) to establish the most suitable test procedure to prepare satisfactory reference strips.

Standard Compounds

Regarding a standard corrosive sulfur compound the use of hydrogen sulfide is ruled out because normally it is not present in finished petroleum products and its addition in known amounts would be difficult. Pure organic polysulfides, such as dibutyl tetrasulfide, are not obtainable and difficult, if not impossible, to prepare. Currently, the use of elemental sulfur or a brand product such as sulfurized dipentene (Ortholeum 202 made by the du Pont Company, consisting of approximately 33 percent sulfur) appear quite promising. Since sulfurized dipentene varies in composition it would be necessary to set aside a batch of this product for reference purposes. In the final production of corrosion standards it is planned that the number of the strip, or degree of corrosion, will be a mathematical function of the amount of corrosive sulfur present.

Regarding a suitable non-corrosive solvent the most promising found to date are pure n-heptane obtained from Westvaco Chlorine Products Corporation and cetane obtained from the du Pont Company.

The most feasible test method to prepare similar standard reference strips appears to be the ASTM D-484 (3 hours at 212° F.) or the ASTM D-130 (3 hours at 122° F.) test. The more drastic and shorter tests give poorer reproductibility than the above methods. If one of the above tests is used it is necessary that the technique or method of test be quite accurately defined. Minor variables affecting reproductibility in these methods are (1) preparation and handling of strip, (2) amount of solvent or oil used in the test and (3) the removal of oil from the strip prior to rating.

Preservation of Standards

Various methods for the preparation and preservation of sets of standard strips have been tried. The current method is to juxtapose them on the inner periphery of a glass jar, the strips being held in position by packing the jar with glass wool, flushing with nitrogen and then sealing the cover. A method of this type is undoubtedly the most desirable since actual strips are used. However, the sets are somewhat clumsy to handle and a considerable amount of time is required to prepare them.

Strips set is viscous liquids such as Canada balsam undergo a color change presumably because of further light interference. Currently, a method of placing the strips between laminated plastics is being investigated. Also, an attempt was made to obtain reproductions by means of colored photography but this method appears to have little promise. A method of printing using colored inks will be investigated.

Conclusions

Sets of tentative copper strip corrosion standards, representative of those strips obtained on all types of light petroleum stocks when using current corrosion test procedures, have been prepared. These standards will be useful not only in classifying light petroleum products with respect to degree of corrosiveness but also in setting, in more exact terms, maximum corrosion limits in the specifications. Some additional work is required to correlate these standards with the actual amount of corrosive sulfur present and to establish the most desirable test method for reproducing the standard strips.

ACKNOWLEDGMENT

Work on this project is being carried out by Messrs. A. J. Steinbach and W. Nelson of the Whiting Research Staff. The writer wishes to thank them for their patience and close observations required in carrying out the numerous tests required for a project of this type.

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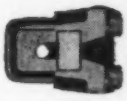

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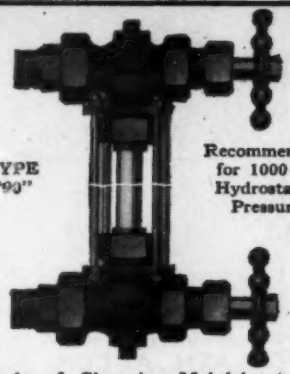

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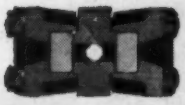

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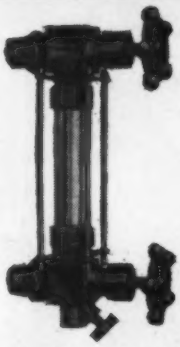

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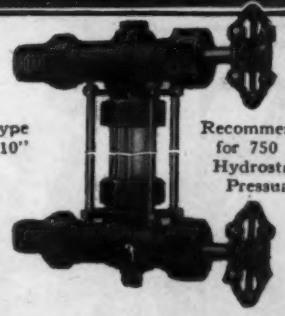


Type "10"

Recommended for 750 lb. Hydrostatic Pressure

Steel construction throughout with stainless steel interior trim. Automatic shut-off is positive and instantaneous; stainless steel balls shut off the flow of liquid when glass breaks. Heavy duty stuffing boxes, union connections, offset construction facilitate cleaning and simplify glass replacement. Conform with A.P.I.—A.S.M.E. requirements.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

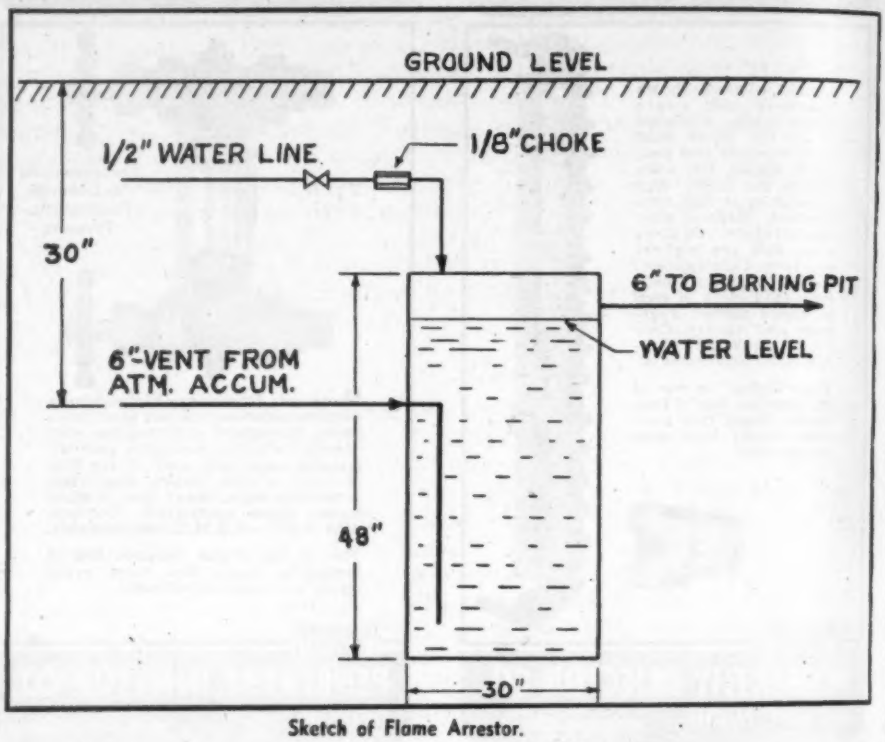
OPERATION HOW TO DO IT MAINTENANCE

HOW TO—

Install Flame Arrestor For Accumulator Vent Gas

THE flame arrestor shown in the accompanying diagram was constructed from a 48-inch section of 30-inch diameter pipe, and is used in the flare vent line from an atmospheric accumulator in a gasoline plant. The vent line from the accumulator is 30 inches below ground level and enters the water seal tank at a point approximately 15 inches from the top. A second 6-inch-line connection is made near the top of the seal tank and conducts the gas to the flare.

The level in the seal is maintained by constant flow of water through a one-half inch line and a one-eighth inch choke. This flow replaces water lost by entrainment of gas through the seal. Operation of the accumulator is such that a vacuum is not reached sufficient to break the water seal.



Sketch of Flame Arrestor.

HOW TO—

Build a Vise for Cutter Heads

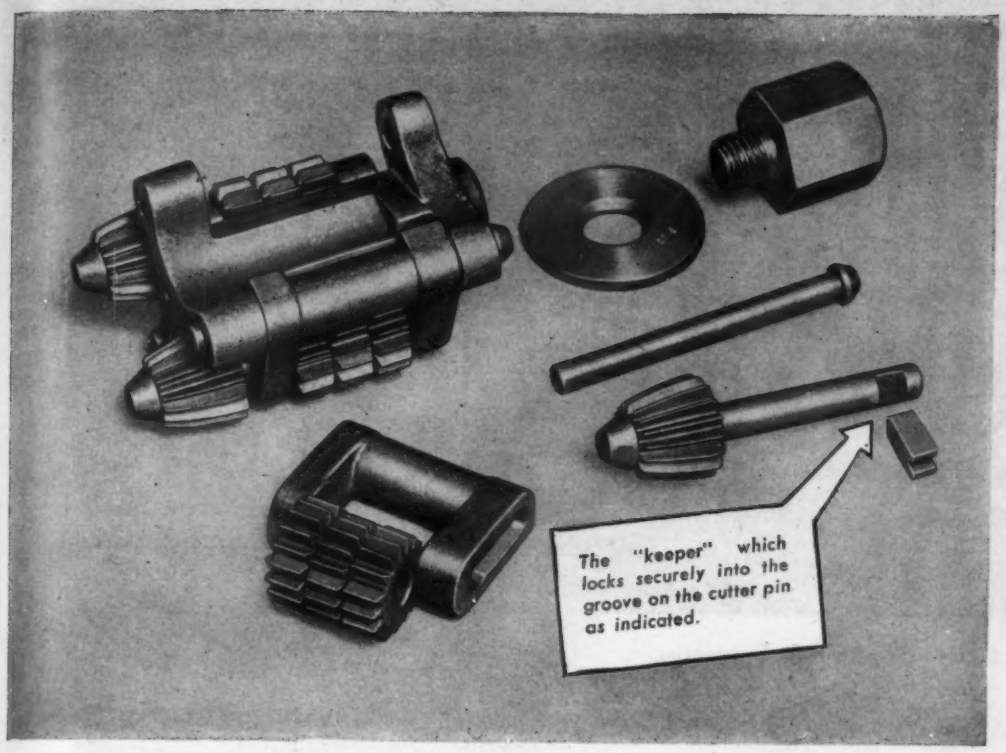
TO SHORTEN the time from stream to stream during a cleanout and inspection, tools which assist the mechanics in changing cutter heads have been found very handy. The vise stand illustrated is built especially for holding the motor solidly and rigidly while the repairman removes and replaces the worn parts with fresh equipment. The stand is made in the form of a tripod, using pipe for the legs, welded solidly to a plate to which the vise is bolted. The assembly is made with as little weight as practicable so it may be moved from one point to another without having to disconnect air hose.

(Photo Courtesy Air Reduction Sales Company)

HOW TO—

Fabricate Piping For Process Units

IN THE fabrication of piping for process units, a technique termed "roll welding" often can be used to advantage in cases where long lines are assembled in pipe alleys or locations with restricted access. A block and fall is rigged at each end of the pipe line being welded. By unwinding, the pipe is turned, allowing the welder to work in the flat or down-hand position, thereby increasing the speed of operation and assuring sound welds.



The new Lagonda long surface, swing frame head with one arm disassembled. It's built in seven sizes to accommodate a size range of 2¼ in. to 6 in. Note the keeper which fits into the slot in the arm and locks securely into the groove in the cutter pin. Assembly and disassembly is quick and easy — no tools are needed for the job.

No threaded cutter pins to break

in the new Lagonda 3300 SERIES SWING-FRAME CUTTER HEAD

There's lots of extra life and service in this new long-surface, swing-frame head for refinery cleaning. A new cutter pin locking device has replaced the former threaded cutter pin which was subject to loosening under service vibration, causing occasional breakage.

Now the cutter pin holds tight — secured by a "keeper" which fits snugly into a slot in the arm and locks firmly into a groove in the cutter pin. This new feature adds mileage to your cleaner performance.

Another advantage of this new Lagonda cutter head is extra swing — the largest expansion ever obtained in a swing frame head! It also has built-in "self-feed," which assures ease of handling. Features such as these have caused users to make such comments as, "Best cleaning we have had in years."

This new head is made to give you uniformly better tube cleaning results when driven by Lagonda 1100 series double ball thrust motors, as illustrated at the left.

Write us for the whole story.

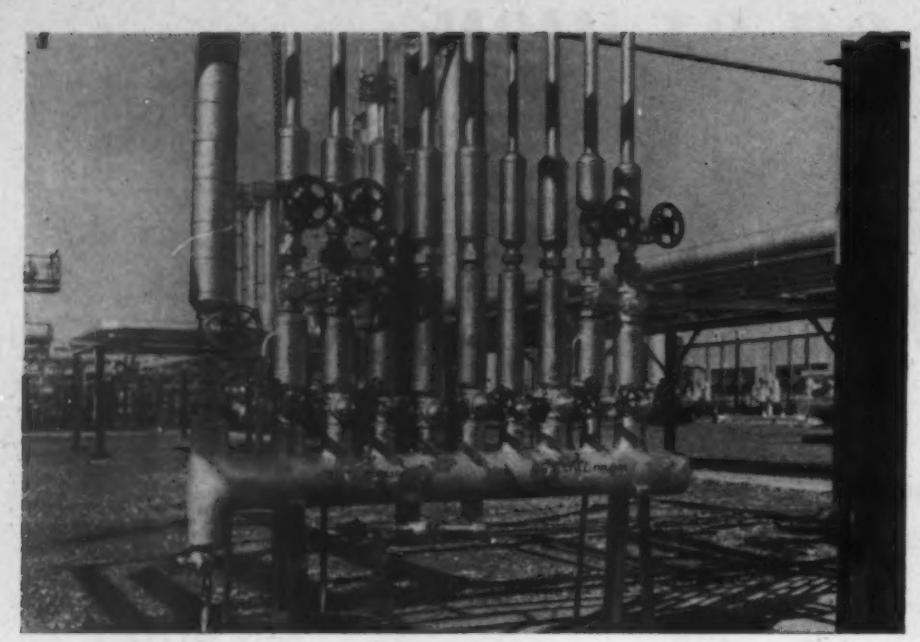
Elliott COMPANY

Lagonda Division, SPRINGFIELD, OHIO

Plants at: JEANNETTE, PA. • RIDGWAY, PA.
SPRINGFIELD, O. • NEWARK, N. J.

DISTRICT OFFICES IN PRINCIPAL CITIES

Y-488



Efficient Steam System to Meet Furnace Emergencies.

HOW TO—

Provide Steam System For Furnace Emergency

A STEAM snuffer system, which was installed during the construction of a gasoline plant, provides an extra margin of safety for two vertical-type direct-fired furnaces in case of an emergency or shutdown. The system consists of a steam manifold located a safe distance from the furnaces, a distillate furnace and a high-pressure still furnace, with lines from the manifold to the dual feed lines, stack, and burner lines of the two furnaces. A utility line for steam hose connection also is provided. Each line and valve and manifold section is clearly labeled to prevent errors in operation.

The manifold provides a constant source of steam for the furnaces, and the construction and accessibility make its operation simple. The lines from the manifold conduct steam directly into the line at various points on each furnace eliminating the use of steam hoses.

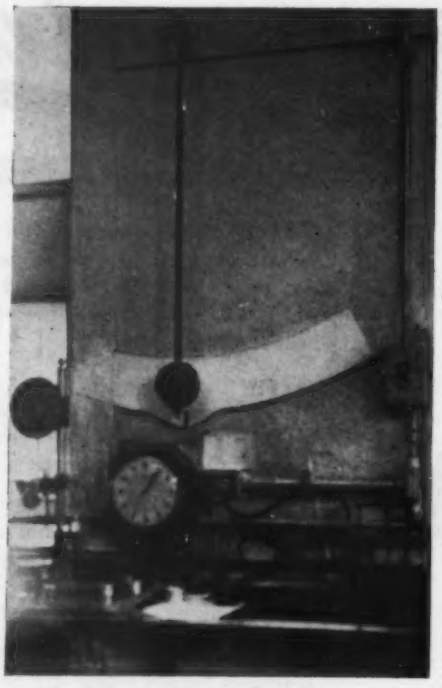
In addition to providing steam during an emergency, the system can be used for steam purging in shutting down the furnace.

HOW TO—

Assure Accurate Visual Timing

FOR visual timing in the inspection laboratory, a pendulum has been found to provide an accurate indicator. The arm is of the length necessary, with the pendulum weight, to indicate exactly one second each time the pointer below the weight passes over a reference mark painted on a placque attached to the wall behind the pendulum.

In use, the laboratory worker merely sets the pendulum in motion and counts off the seconds until the inspection process is completed. The top of the pendulum-arm is attached to a hanger without springs or operating movement, and simply swings until the forces of gravity brings it to a stop, yet, regardless of the arc of the swing, the timing is accurate.



Handy Visual Timing Device.

HOW TO—

Make Elevator Bucket For Filling Towers

A SERVICEABLE elevator bucket can be made with a heavy-duty oil drum for the container. One of the heads is removed with a cutting torch, or by cutting away near the chime with a cold chisel and a hammer. Pieces of rod, or pipe are welded on either side an inch or so nearer the top than the bottom, as trunnions to which the lifting bail is to be attached. The bail may be made of any available rod, with a ring in the upper end for attaching a snatch block or to clamp a wire line end. Pouring material from this bucket is easy, requiring little effort to tilt when raised to the point where the material is to be used.

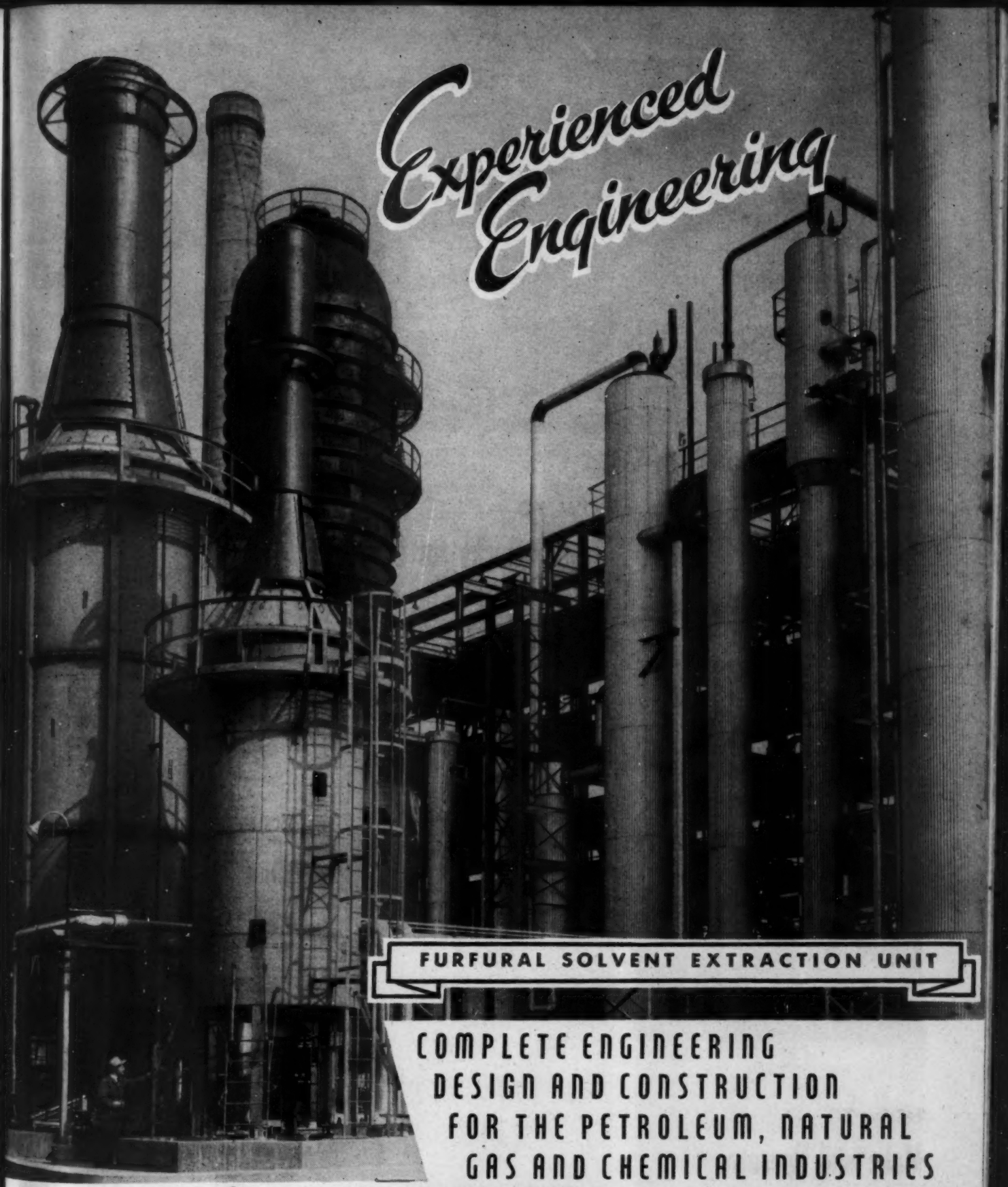
Elevator Bucket for Filling Towers.

HOW TO—

Reclaim Gate Valves With Special Jig

SHELL Oil Company, at its Houston refinery, makes use of a specially built jig for machining valve wedges in reclaiming worn gate valves. Because valve

Special Jig Used by Shell.



FURFURAL SOLVENT EXTRACTION UNIT

COMPLETE ENGINEERING
DESIGN AND CONSTRUCTION
FOR THE PETROLEUM, NATURAL
GAS AND CHEMICAL INDUSTRIES

LICENSED
ENGINEER CONTRACTORS
FOR
TEXACO DEVELOPMENT
CORP.
HOUDRY PROCESS
CORP.

PROCESS Engineers, Inc.

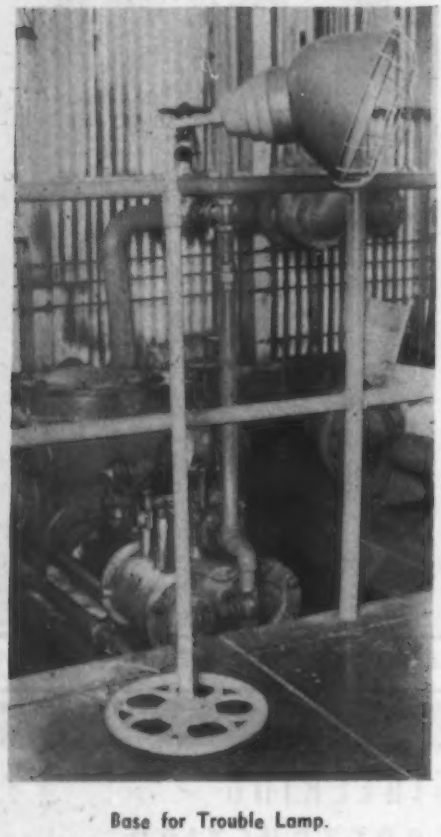
2409 ROSS AVENUE DALLAS, TEXAS

wedges are tapered, the task of positioning them in an ordinary lathe chuck is tedious and time consuming. With this special chuck, the wedge is quickly aligned for machining.

HOW TO—

Build Solid Base For Trouble Lamp

FOR plenty of illumination on the spot where work is to be accomplished in dark pump rooms or at night, the portable flood light shown in the photograph can be set at any angle. Connect the light fitting through an adjustable swivel to a pipe standard threaded into the center hole of a large bandwheel from a discarded gate valve. The weight of the cast wheel is sufficient that the floodlight is not easily upset.

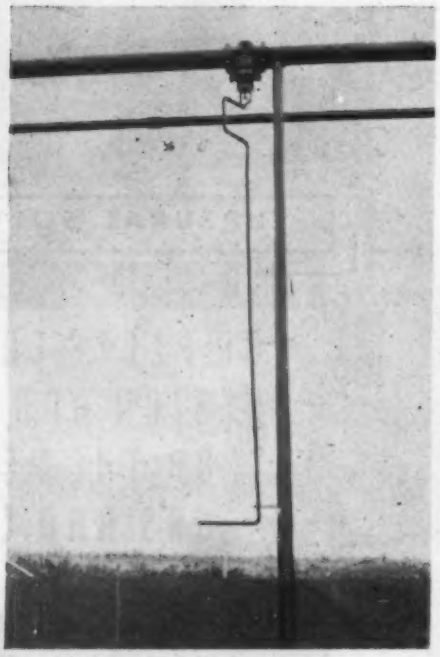


Base for Trouble Lamp.

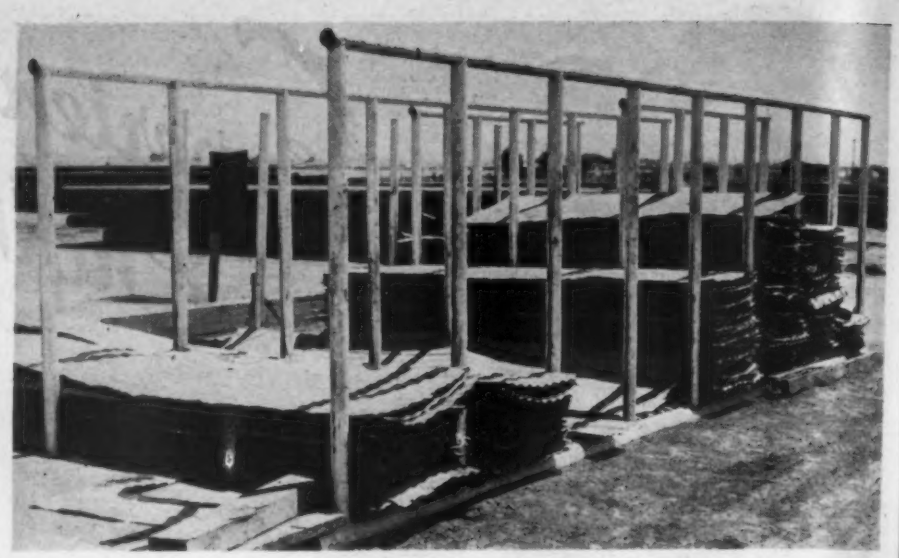
HOW TO—

Make and Operate Plug Valve Wrench

IF A vapor line is carried on supports above the normal reach of an employe, and, perhaps, light wire conduit lies immediately below, he plug valve sometimes is in an awkward position. However, opening and closing can be made easy by attaching a rod to the stem of the valve after bending a sharp crank-like angle in the rod so as to clear the conduit when turning the valve. This arrangement saves use of a ladder and an employe can operate the valve as easily as if it were shoulder high.



Handy Valve Wrench.



Racks, easily built, and shown above, enable companies to keep corrugated iron sheets in orderly stacks.

HOW TO—

Arrange Racks for Corrugated Iron

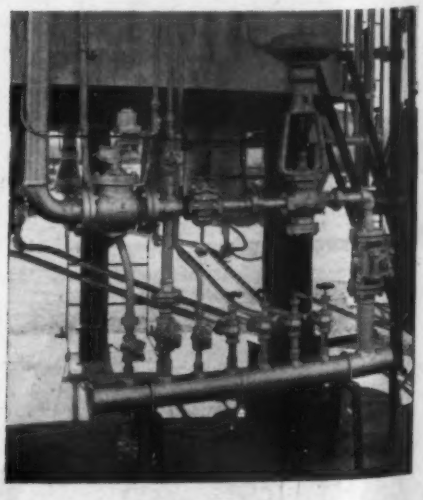
CORRUGATED iron—new or used—is fast becoming less available, so many companies are hastily retrieving all such material that they can from little-used installations in the field, and stacking it in their storage yards. A neat, efficient rack built up out of salvaged pipe materials is used by one company in its storage yard. It is divided into compartments so that sheets of different lengths and various grades of quality of each length can be segregated.

Stringers of salvaged six-inch casing were laid down along the ground and three-inch uprights approximately eight feet tall were welded at the proper intervals along the top side of the base members. The uprights were then tied together at the top by three-inch stringers. Steel slats, made of sucker rod or any bar material, were welded across the length of each section to lend ample level support to each individual pile of sheeting.

HOW TO—

Simplify Furnace Burner Manifold

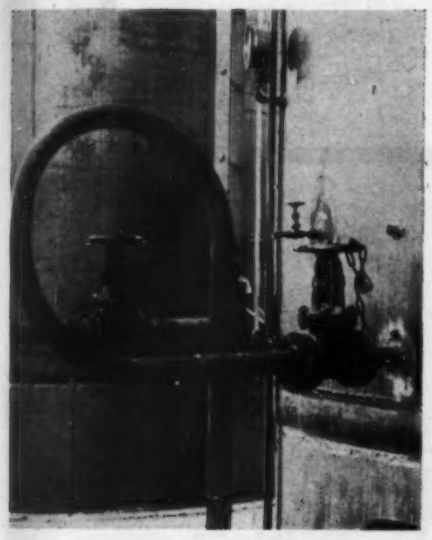
THE installation in the accompanying photograph presents an economical and simple method of manifolding the burn-



Simple Manifold Arrangement for Burners.

ers in a vertical type gasoline plant furnace. All valves for controlling fuel to the burners are at the one location. Fuel gas enters at the left through a solenoid safety shutoff valve and rate of flow control valve to the burner manifold. The method of piping utilizes the manifold as one leg of the control valve bypass system, in addition to grouping all control valves at one location.

Each burner is served by a manual control valve that can be used for individual adjustment of the burners, or when repairs are needed, the valve can be closed and the burner disconnected and removed without shutting down the furnace. As shown, all valves are easily accessible.



Bend to Absorb Expansion.

HOW TO—

Make Pipe Bend To Absorb Expansion

WHERE piping and connections are subjected to abnormal strain due to temperature changes or vibration, the shock can be absorbed with a full loop placed in the pipe near the point where it is connected to the tank or vessel. Precautions should be taken when making the bend so as not to distort the walls of the pipe. The bend can easily be made by filling the bended section with dry sand, jarred tightly in the pipe and afterward plugging the ends to prevent the sand from moving. A template, or small circle of wood, or metal, facilitates the bending.

HOW TO—

Install Vertical Pipe Supports

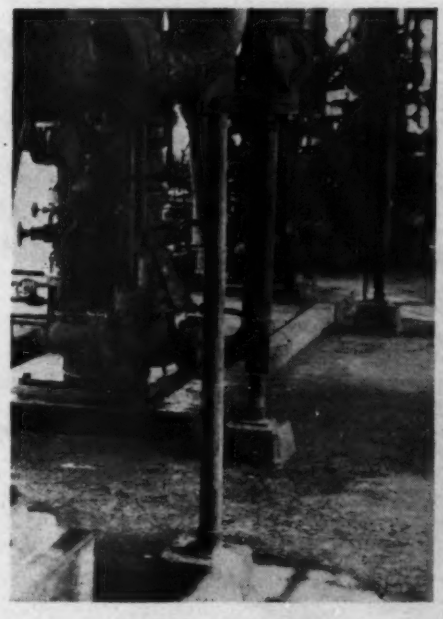
AS A support for fittings connected to piping at process pumps where the connections and risers join overhead pipe lines in a gasoline plant, 2-inch standards can be installed beneath the outside ell. Concrete blocks are poured as a base for the standards which are set in

Handy Storage Board for Tools — A plant Necessity.

HOW TO—

Build a Handy Tool Storage Board

AN EFFICIENT tool storage board can be made of ply-wood having two wide sides and tapering ends. Moulding at the seams add to the appearance of the unit. Picture hooks screwed into the face of the varnished ply-wood supply means of hanging the tools, after cleaning and inspection, in their proper positions. Pipe wrenches from 6-inch to 36-inch are grouped near one end, while adjustable and open-end wrenches occupy other portions of the panels. Packing hooks hang where they are immediately available with a screw plate grouped along the lower part of one end.



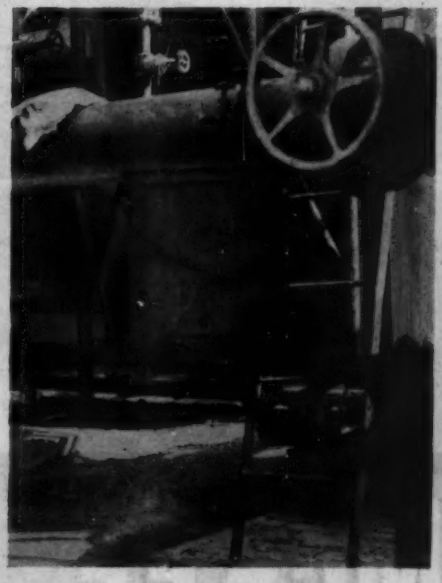
Neat Support for Fittings.

flanged fittings. Wing straps are welded to the outside of the ells to attach the standards with bolts. Measurements are exact so that all of the weight of the pipe and fittings is supported by the standards.

HOW TO—

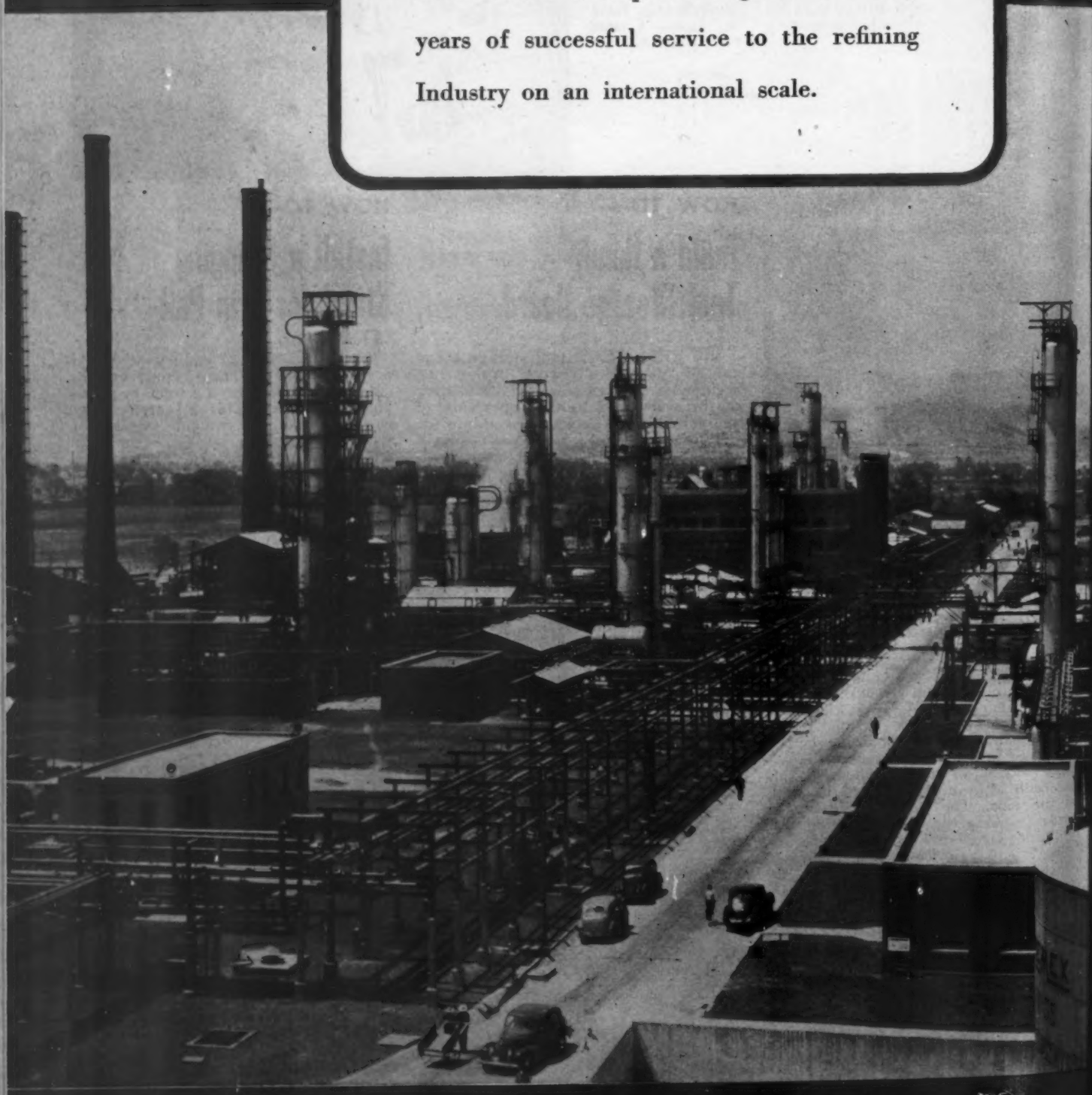
Install a Swinging Stand for Drip Pail

THE appearance of equipment can be preserved, and fire hazards prevented by catching the drip from sample cocks on absorption lines. This is accomplished easily by use of a swinging stand upon which a pail can be set. The plant welder can cut a bracket from a sheet of salvaged tank steel, improving its looks with a couple of circular holes. A pipe post is set firmly in the ground and may be tamped in place or grouted by pouring concrete mix into the hole around the post. The bracket is welded to a ferrule of larger pipe so as to slip easily over the top of the post and prevented from sliding downward by a ring welded at the desired point to support the ferrule and bracket. A shallow pan of heavy sheet steel is tacked to the bracket with a lip to prevent the pail from slipping around when the sample is being taken.



Swing Device for Drip Pail.

The sound, practical refinery engineering available to you in the McKee organization is the result of experience gained in many years of successful service to the refining Industry on an international scale.



McKEE

UNDIVIDED RESPONSIBILITY IN ONE ORGANIZATION

Synthetic Fuels Technology Well Advanced, Interior Department Expert Tells Senate

Technology of producing synthetic liquid fuels from coal, oil shale and natural gas probably is as far advanced today as was synthetic rubber technology at the beginning of World War II.

This was the testimony of Dr. W. C. Schroeder, chief of the Interior Department's liquid fuels research program before a Senate committee recently. Dr. Schroeder said that if the United States faced an immediate national emergency, a synthetic fuels industry capable of producing two million barrels daily could be developed in from two to four years through use of unlimited funds and manpower.

Later developments, he said, would outmode facilities built on today's available knowledge, but given a year or possibly longer, he said that technology could be developed to a point where plants could be designed and built to stand for a long period without becoming outdated.

Government's Costs

He estimated that current cost of synthetic fuel production as shown by the government's pilot plant, will run 8 to 10 cents per gallon, not counting interest on investment. Only cost figures he could present were on production by coal hydrogenation where cost of 7 to 10 cents per gallon is indicated when interest is figured at 2 percent and a 4-percent profit is allowed.

Dr. Schroeder gave the following outline of possible development of synthetic fuels (requirements for plants with capacity of 10,000 barrels daily each):

Oil Shale—Nearby source of 15,000 tons shale daily over 25-year period. Water supply 1.7 million gallons daily. **Comment:** Present cost of production is $2 per barrel of low-grade oil. Enough knowledge now exists to permit commercial competition with bunker and diesel oils. If I had enough money, I'd seriously consider going into business of producing oil from shale.

Natural Gas—If daily gas consumption was 120 million cubic feet and life of plant 20-25 years, a nearby source of one trillion cubic feet would be required. Water supply, 15 million gallons daily. **Comment:** Southern Gulf Coast only suitable area and a plant at Brownsville, Texas, is under construction. Estimated gas reserves available for synthetic production is 40 trillion cubic feet which could be converted into about 4 billion barrels of liquid fuels.

Coal—Construct plant at mouth of mine that has coal at least eight feet thick and covering 5 square miles in area. Water, 5 to 8 million gallons daily. **Comment:** This technology has not been as far advanced as experiments in natural gas. In regard to the Fischer-Tropsch process in coal gasfication, a complete plant has not yet been designed in the U. S. and work still is incomplete on designs for converting chambers.

Conversion of the Missouri Ordnance Works near Louisiana, Mo., from synthetic ammonia to synthetic liquid fuels production, started late in 1945 by the Bureau of Mines, again is under way following an extended delay caused when the plant was taken back by the War Department for emergency production of ammonia for fertilizers, Secretary of the Interior J. A. Krug has reported.

The Bureau recently took over the $17 million plant and completed the return transfer of 79 engineering and administrative personnel from Torrance, Calif., to Missouri on July 20, approximately a year after the property was returned to the War Department at direction of the Office of War Mobilization and Reconversion.

Design work continued during the year at Torrance, which is the headquarters for Bechtel Corporation, which holds a $6,780,000 contract for engineering, design and construction necessary under the conversion program. Equipment, grading, and housing subcontracts totaling approximately $4 million have been placed. The construction schedule calls for the Missouri plant to be producing gasoline and oil from coal and lignite by June 30, 1948.

Heavy rainfall and high water at the plant site—about 100 miles above St. Louis on the Mississippi River—have delayed excavation, construction, and movement of materials.

New structures to be erected in an area just south of the present ordnance plant will include coal and paste preparation buildings, a compressor house, four pump houses, two control houses, coal hydrogenation stalls, an oxygen unit, a shop, a change house, and several small buildings. Many of the ordnance plant's existing facilities and equipment can be used with little modification by the Bureau of Mines, saving several million dollars in construction costs.

Synthetic fuel plants in England—and formerly in Germany—frequently are or were operated in connection with synthetic ammonia plants to obtain the most efficient use of raw materials, plant, and personnel. Centrally located with respect to all major coal fields of the United States, the new synthetic fuels demonstration plant will test fuels from several to determine their suitability for making synthetic oil and gasoline. To be operated in conjunction with a research and development laboratory at Bruceton, Pa., the plant will serve as a provinng ground for processes developed to convert part of this country's immense coal reserves into liquid fuels to supplement our petroleum resources.

Meetings

August

25-27—Appalachian Gas Measurement Short Course, West Virginia University School of Mines, Morgantown.

27-29—Short course "Instrumentation for Process Industries," Texas A. & M. College, College Station.

September

8-12—Instrument Society of America, conference and exhibit, Stevens Hotel, Chicago.

15-17—National Butane-Propane Association, Jefferson Hotel, St. Louis.

15-19—American Chemical Society, Division of Petroleum Chemistry, annual meeting, Waldorf-Astoria, New York.

17-19—National Petroleum Association, Hotel Traymore, Atlantic City, New Jersey.

23-25—Pacific Coast Gas Association, Coronado Hotel, San Diego.

29 to Oct. 3—American Gas Association, San Francisco.

October

6- 8—American Society of Mechanical Engineers, Petroleum Mechanical Engineering conference, Rice Hotel, Houston.

16-18—National Lubricating Grease Institute, annual meeting, Edgewater Beach Hotel, Chicago.

20-24—Annual Meeting, American Society for Metals, Palmer House, Chicago.

20-24—Annual Meeting, American Welding Society, Sherman Hotel, Chicago.

21-25—Pacific Chemical Exposition, San Francisco.

November

6- 7—Society of Automotive Engineers, fuels and lubricants meeting, Hotel Mayo, Tulsa.

10-13—American Petroleum Institute, Stevens Hotel, Chicago.

December

1- 5—American Society of Mechanical Engineers, annual meeting, Atlantic City, N. J.

29-30—Fourteenth Annual Chemical Smyposium, American Chemical Society, Chicago.

Texas A. & M. Instrument Course Set for August 27-29

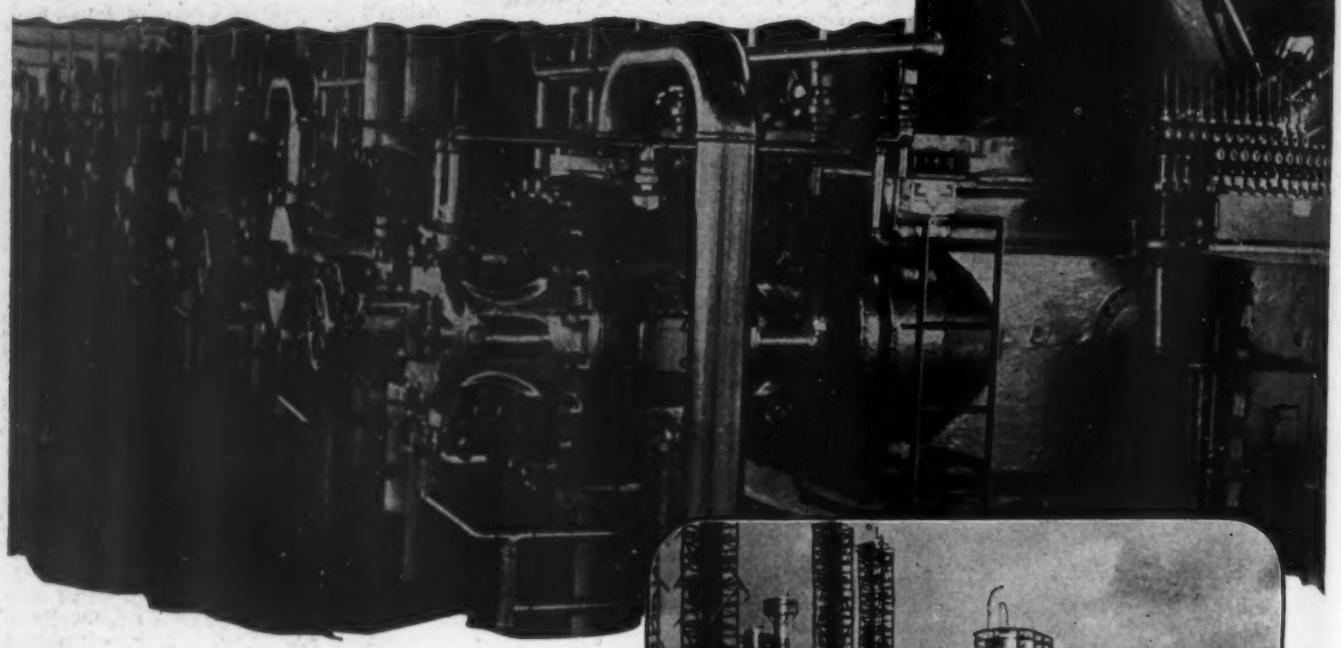
"Instrumentation for the Process Industries," the second annual short course held at A & M College of Texas at College Station, has been announced for August 27, 28, and 29, according to P. G. Murdoch, of the department of chemical engineering. The courses are designed to lead to an improved understanding of the principles and practice of instrumentation as applied to the continuous fluid-flow process industries. The program announced includes presentation of papers by outstanding men directed toward instrument, design, process, and operating engineers.

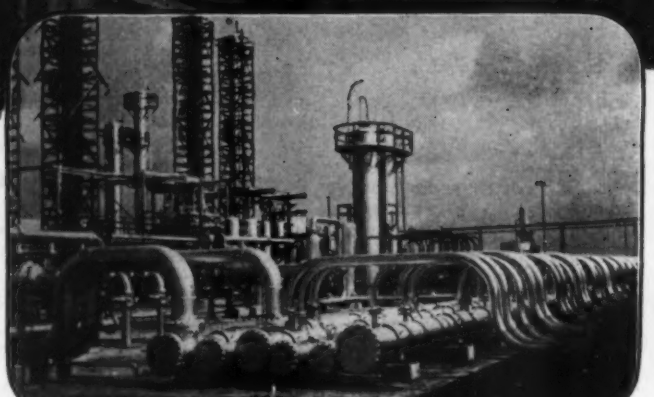
Wednesday—Dr. C. M. Blair, Carbide and Carbon Chemicals Corporation, Texas City, will present "Economics of Instrumentation in the Process Industries"; "Functions and Responsibilities of a Plant Instrument Department" by J. G. Kerley, Shell Oil Company, Inc., New York City; "Coordinated Process Control Systems and Some Unusual 'Angles' Dealing with their Design, Installation, and Initial Operation" by F. H. Trapnell, E. I. du Pont de Nemours and Company, Wilmington, Delaware, and "Instrumentation for Speed Control" by J. G. Wilson, Shell Development Company, San Francisco, California.

Thursday—"Instrument Work in an Atomic Energy Laboratory" by H. U. Fisher, Monsanto Chemical Company, Dayton, Ohio; "Instrumenting a Con-

G-MV EFFICIENCY

for a Multi-purpose plant in Venezuela





PRESSURE MAINTENANCE . . . crude stabilization . . . gas dehydration . . . gasoline extraction . . . crude topping. This is the broad variety of operations performed at the modern plant of the Compania Consolidada de Petrolea in the Jusepin area of Venezuela. Here, seven Cooper-Bessemer GMV's, modern V-angle units, meet all compressor requirements; can handle up to 25 million cubic feet of wet gas daily through 3 stages of compression, while supplying 15 field injection wells at a maximum 2500 psi. All seven GMV's, one vacuum and six 3-stage compressors, are 6-cylinder, 600 hp units. If you are not entirely familiar with GMV features and advancements, send for the new GMV Bulletin No. 337 and have at hand complete, comprehensive information on these outstanding 400, 600, 800 and 1000 hp units.

INSERT: General view of compressor manifold piping, gas dehydrating unit and towers at plant of Compania Consolidada de Petrolea, Venezuelan subsidiary of Sinclair Consolidated Oil Company.

ABOVE: Battery of seven modern Cooper-Bessemer V-angle units, one vacuum and six 3-stage compressors, each a 6-cylinder, 600 hp GMV.

The
Cooper-Bessemer
Corporation

MOUNT VERNON, OHIO — GROVE CITY, PENNA.

New York Washington Bradford, Pa.
Parkersburg, W. Va. San Francisco, Calif. Houston, Dallas, Greggton, Pampa and Odessa, Texas
Seattle, Wash. Tulsa Shreveport St. Louis Los Angeles Caracas, Venezuela

tinuous Chemical Process" by H. C. Frost, Corn Products Refining Company, Argo, Illinois; "Sea Water Bromine Process Chemical Control Systems" by Porter Hart, Dow Chemical Company, Freeport, Texas, and "The Instrumentation of a Hydroformer" by R. H. Koehler, Pan American Refining Corporation, Texas City.

Friday—"Instrumentation of Cycling Plants" by A. J. L. Hutchinson, The Fish Engineering Corporation, Houston, Texas, and "Instrumenting Physical Methods of Chemical Analysis" by Nelson Gildersleeve, General Electric Company, Schenectady, New York.

A question and answer period with a selected panel to answer questions and lead the discussion for an interchange of ideas will close the short course Friday. A portion of each day of the sessions will be devoted to inspection of exhibits sponsored by various instrument manufacturers in an effort to inform those attending of recent developments in the instrument fields, also several papers have been prepared that describe some of the newer instruments and their applications.

Refinery Workers Return To Pure Company Plants

Prolonged strikes by refinery workers at two plants of The Pure Oil Company have been settled, as contended by the company, and contracts signed on a local basis. The shutdown at the Cabin Creek refinery near Charleston, W. Va., was for 117 days whereas the company's largest refinery, at Nederland, Texas, had been struck for 109 days. At the latter point "new construction has been delayed and it is now difficult to predict when new units will go into operation," a company statement said. "It is possible that some of the work originally planned may not now be undertaken in the immediate future."

Processing of approximately 32 million gallons of petroleum products was interrupted by the Cabin Creek strike and more than $250,000 in wages was lost by these employes. As a result of the Texas strike, 240 million gallons of petroleum products were lost to the consuming public and some $850,000 in wages were lost to the employes and the community.

Standard of California Promotions

W. H. SPAULDING

W. H. HALES

APPOINTMENT of W. H. Hales as chief engineer of its manufacturing department has been announced by Standard Oil Company of California.

Hales, a 1923 Stanford University graduate, came to work for Standard in 1924 as a construction superintendent at the company's El Segundo refinery. Most of his service with the company since that time has been at El Segundo and at Standard's Richmond refinery. He was made chief engineer of the Richmond plant in 1943.

Other manufacturing department appointments also announced include those of W. H. Spaulding as assistant chief engineer, and J. O. Ciprico as designs engineer.

Spaulding started with Standard in 1938 after taking a master's degree at Massachusetts Institute of Technology. He was departmental job engineer prior to his new appointment. Ciprico has worked in various engineering capacities for the company since 1919, following graduation from the University of California.

J. O. CIPRICO

Contracts Are Awarded for Texaco's East Coast Plant

Construction contracts for two major units of The Texas Company's new refinery on a 1368-acre site at Eagle Point, N. J., in the Philadelphia-Camden area have been awarded to Foster Wheeler Corporation and The M. W. Kellogg Company. Foster Wheeler will build the initial 42,000-barrels-per-day crude and vacuum distillation unit, while an accompanying fluid catalytic cracking unit for the production of gasoline will be constructed by Kellogg. In addition, Texaco expects to place contracts for a solvent refining unit, power plant, tankage, and docks.

Texaco announced it had purchased three, 7500-kilowatt turbo-generators from Westinghouse Electric Corporation. Dredging and site clearing contracts have been awarded to Gahagan Construction Corporation, Edward H. Ellis & Sons, Thomas A. Reilly Company, and Brokaw Land Clearing Company.

It is estimated that the plant will be completed in about two years.

This will be the company's first major East Coast refinery, W. S. S. Rodgers, Texaco's board chairman, pointed out. It will be strategically located, he said, to receive both foreign and domestic crude oil.

The refinery, according to the Texaco chairman, will be an ultra-modern plant incorporating the benefits of wartime petroleum research and technological advances in refining. In the first phase of its operations, it will process motor fuels, diesel fuels, and furnace and industrial fuel oils.

Other products will be announced as additional refinery units are constructed. The refinery is a key project in Texaco's postwar expansion program. It will be the company's twenty-first plant for processing petroleum. Its other 20 refineries are spread from coast to coast.

Houston Plant Sold

War Assets Administration last month approved sale of the wartime aviation gasoline plant operated by Eastern States Petroleum Company, Inc., to that

Thank you, Leonard !

WESTERN UNION

JOSEPH L. EGAN, PRESIDENT

SYMBOLS
DL = Day Letter
NL = Night Letter
LC = Deferred Cable
NLT = Cable Night Letter

(28)

RECEIVED
JUN 5 1947

CLASS OF SERVICE
This is a full-rate Telegram or Cable-gram unless its deferred character is indicated by a suitable symbol above or preceding the address.

The filing time shown in the date line on telegrams and day letters is STANDARD TIME at point of origin. Time of receipt is STAN

A. V. D.

P.ZA536 PD=WUX ALMA MICH JUNE 5 513P
ARTHUR V DANNER EXEC VICE PRESIDENT=
HOUDRY PROCESS CORP PHILA=

HAVE JUST COMPLETED TEST RUN ON TCC UNIT THE GASOLINE YIELD AND THE OCTANE NUMBER ARE BOTH A LOT HIGHER THAN THE GUARANTEE IN THE CONTRACT
REID BRAZELL PRESIDENT LEONARD REFINERIES INC.

.TCC.

M ITS PATRONS CONCERNING ITS SERVICE

Compact but complete, Leonard's new 3,000 b/d TCC unit includes all the essentials of cat crackers many times its size. It is actually simpler, with an integral elevator design so that only one elevator is required for both spent and regenerated catalyst.

WE LIKE TO GIVE MORE THAN WE PROMISE!

Leonard Refineries' new 3,000 b/d TCC unit has completed its test run with results that are gratifying alike to Leonard and Houdry.

Contractual guarantees, both as to yield and quality, have been exceeded by wide margins.

The successful performance of this first post-war small-scale TCC unit—and its extreme flexibility of operation—are no mere matters of chance or circumstance. Starting with TCC's inherent advantages of basic design, the unit has been well-planned, well-built, well-run. From the day it went on blue prints to the day it went on stream, every step of its development was under the constant, close supervision of Houdry engineers.

We are grateful for Leonard's expression of complete satisfaction with its new small TCC. It is representative of the respect the industry holds for the processes and services of Houdry.

Leonard generously authorizes us to invite interested refiners to visit its refinery at Alma, Michigan, and to observe at first hand the operation of this new small TCC unit.

HOUDRY
CATALYTIC
PROCESSES

HOUDRY PROCESS CORPORATION

25 Broad Street, New York 4, N. Y.

THE MONTH...

company for $2 million. Original cost was in excess of $10 million. No down payment will be required if the purchaser expends $400,000 or more in capital improvements during the next two years. Price is payable at rate of $20,000 monthly for the first two years and $30,000 monthly thereafter.

Purchaser is given privilege of buying equipment on plant site within six months at prices to be fixed by WAA.

Natural Gasoline Plant Projected for Louisiana

Sixteen Louisiana oil producers have become part owners of a natural gasoline extraction plant which is being constructed under the supervision of Sun Oil Company in the Delhi, West Delhi and Big Creek oil fields. The plant will process approximately 17 million cubic feet per day of casinghead gas.

The new plant, under construction on a 40-acre site in Richland Parish, will extract 70,000 gallons per day of liquid hydrocarbons including propane, butane and natural gasoline. The remaining dry gas will be piped to a connection with a natural gas pipe line company and sold as fuel.

Approximately 80 percent of the producers in the three fields have agreed to join in ownership and operation of the plant. Each company engaged in the venture will own an interest in the plant equivalent to the percentage of ownership held in the producing area. Each company will produce and sell its own share of the natural gasoline and other products recovered.

Sun Oil Company and C. H. Murphy, Jr., jointly own approximately 64 percent of the producing acreage. Sun has been designated as operator and will have charge of the construction, operation and maintenance of the plant.

Petroleum Engineering, Inc., of Houston, is the builder.

Cleveland Norcross Joins American Physics Institute

Cleveland Norcross, formerly executive secretary of the Office of Scientific Research and Development, became assistant director of the American Institute of Physics on July 1.

Dr. Henry A. Barton, Director of the Institute, explained that in creating the post of assistant director, the Institute is recognizing and providing for the increased responsibilities and activities whch physicists and ther organization are now called upon to undertake in cooperation with government, industry, education and other professional fields.

Norcross, a native of Colorado, is a graduate of the University of Pennsylvania's Wharton School of Finance and Commerce.

In 1940 he became interested in assisting the Office of Scientific Research and Development, then the National Defense Research Committee, to build up its staff. In October of that year he joined this strategic wartime agency as administrative officer and assumed responsibility for all OSRD administrative and contractual matters.

JOHN H. SCHAEFER

Ethyl Vice President Moves to Baton Rouge

John H. Schaefer, vice president in charge of manufacturing and transportation for Ethyl Corporation, has transferred his headquarters from New York City to Baton Rouge, to supervise operations there.

The integrated manufacturing plant there is the largest of its kind in the world, producing most of the intermediate chemicals required in manufacturing antiknock compounds to improve the quality of gasolines. Recently, the company announced a $20,000,000 construction program to increase the manufacturing facilities.

Schaefer was appointed manager of the manufacturing and transportation facilities of Ethyl Corporation a year after he joined the company 21 years ago, and was elected a vice president in 1943. He is a director of Ethyl Corporation, Ethyl Dow Chemical Company, the Industrial Research Institute, the Lead Industries Association, and the Chemical Corps Association, and a member of the American Section of the Society of Chemical Industry.

Skinner, Caesar Receive Educational Grants

Philip D. Caesar, Paulsboro, N. J., and William C. Skinner, Dallas, are recipients of the first educational grants made by Socony-Vacuum Oil Company, Inc.

Socony-Vacuum established the grants to enable outstanding technical employes in its laboratories to study for advanced degrees. Candidates were required to have a bachelor's degree and to have been employed by the company for at least two years.

Recipients will receive full pay for the length of time necessary to earn degrees of doctor of philosophy at accredited schools of their choice, beginning with the fall term. It is anticipated that such an award will be made annually.

Continental and Cities Service to Build Plant

Through a partnership in Citron Corporation, Cities Service Oil Company and Continental Oil Company will build a new lubricating oil plant near Lake Charles, Louisiana. It has been announced as "the largest plant in the United States for the manufacture of solvent refined lubricating oils." The cost will be around $30,000,000.

A site of 162 acres recently was purchased between existing plants of the two companies.

The plant has been designed to produce 6000 barrels daily of 95 VI oils and will have facilities for making various grades of bright stock, neutrals and fully refined crystalline waxes. The contracts for construction have been let to the Lummus Company and to the Max B. Miller, Company, New York. Construction will begin later this year.

The corporation is owned 65 percent by Cities Service Oil Company and 35 percent by Continental Oil Company. W. Alton Jones, president of Cities Service is chairman of the board and Burl S. Waton, vice president of that company, is president of the partnership corporation. Harold Osborn, vice president of Continental Oil Company in charge of its manufacturing activities, is vice president, as is A. P. Frame, vice president of Petroleum Advisers. These and H. L. O'Brien, L. D. Mann and G. L. Mateer of Cities Service; E. F. Battson, Serge B. Jurenev and F. W. Mann of Continental make up the directors.

F. W. Simpson has been named resident general manager.

Dean of School of Chemistry At Penn State College Dies

Frank Clifford Whitmore, dean of the school of chemistry and physics at Pennsylvania State College, died suddenly at his home in State College June 24, 1947. He also was research professor of organic chemistry. He had been dean of the department since 1929. Dean Whitmore was a graduate of Harvard University, where he received his doctor's degree in 1914. Before going to Penn State he taught at Williams College, Rice Institute, the University of Minnesota and was chairman of the chemistry department at Northwestern University.

Among the scientific honors that came to him were the William H. Nichols Medal in 1938, when he was president of the American Chemical Society, and the Willard Givvs Medal in 1945. He was elected to the National Academy of Science in 1947.

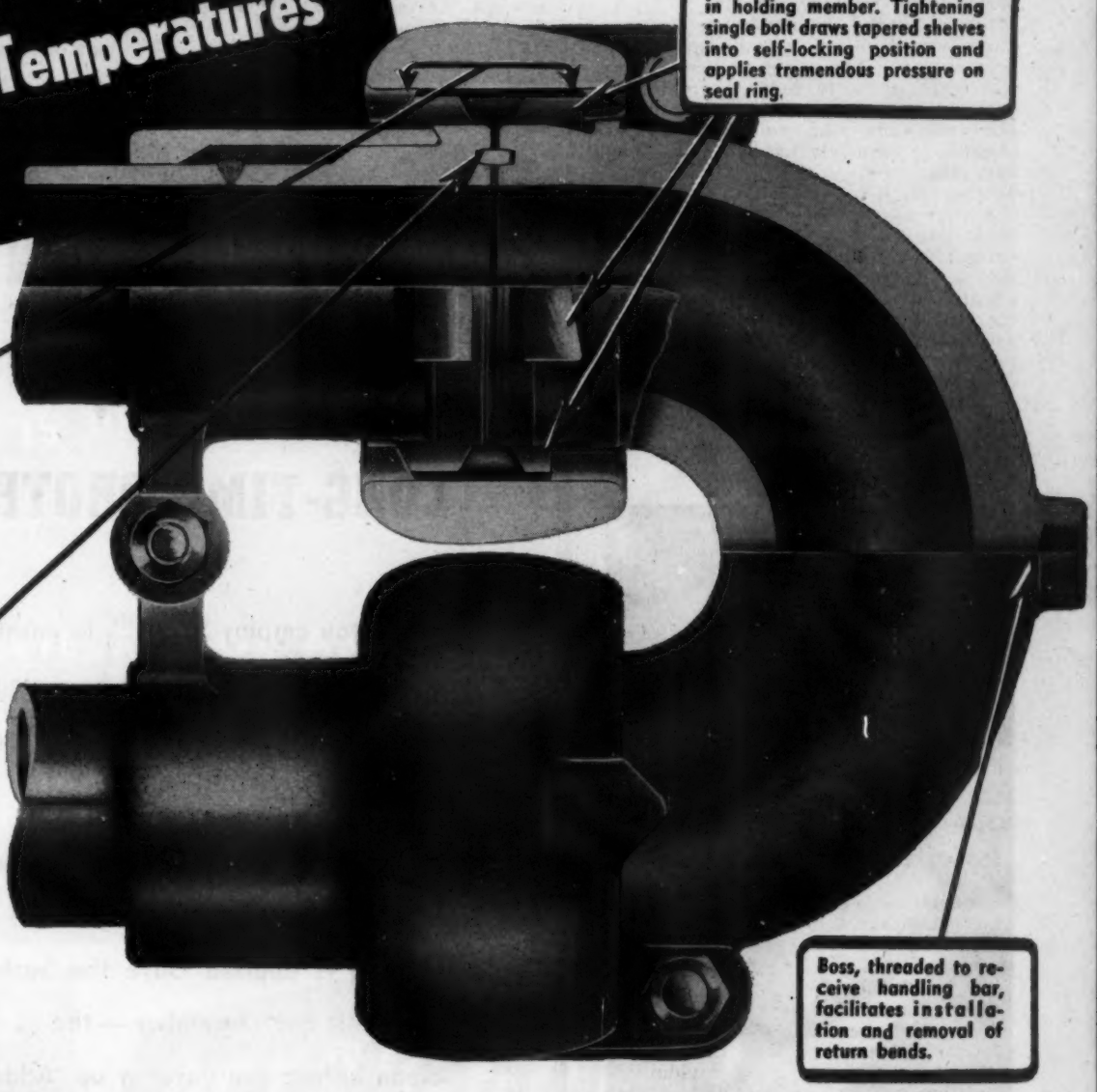
His writings included Organic Compounds of Mercury and Organic Chemistry in addition to more than 200 scientific and technical papers.

His work in behalf of the petroleum refining industry was summed up as follows in the news release that came from Pennsylvania State College following his death:

"Dean Whitmore had long been interested in petroleum. Before coming to Penn State he studied the sulfur compounds in petroleum. His work in aliphatic chemistry was applied in many ways to new petroleum products or refining methods. While at Penn State he and his colleagues synthesized approximately 300 different hydrocarbons. These

Why Unibolt Furnace Fittings Seal Even The Lightest Gases At Extreme Temperatures

Inside Story



9-degree tapered shelves made integral with return bend body, interlock with identical shelves in holding member. Tightening single bolt draws tapered shelves into self-locking position and applies tremendous pressure on seal ring.

Short distance between points of support minimizes contraction and expansion. Initial seat pressure maintained uniformly throughout temperature cycle.

Loose metal seal ring seats in 18-degree included angle in ring grooves, providing additional multiplication of pressure applied to the bolt (Total: 20 to 1). Ring and grooves machined to such close tolerances that distorting pressure need not be applied to effect seal.

Boss, threaded to receive handling bar, facilitates installation and removal of return bends.

The fact that UNIBOLT Streamlined Return Bends may be depended upon to provide a dependable seal of light gases under elevated temperatures has been proven on a number of installations where furnace outlet temperatures range up to 1600 degrees F. *This positive seal is accomplished by tightening a single bolt . . .* No rolled-in tubes, no seal welding, no tapered plug closures, no lapping to make a seal, no need for steam in the header boxes. They permit faster "heading up," replacement of a single tube and returning any return bend body to any two tubes. Completely interchangeable parts assure low-cost maintenance.

For complete details, write for Bulletin No. R-42.

NEW TYPE TUBE ALIGNING - ANCHOR CLAMP

The UNIBOLT Tube Aligning-Anchor Clamp serves two purposes: It provides a rigid support for the furnace tubes when the return bend body is removed for tube inspection. Heretofore, the tubes might move out of position when the bend was removed. The clamp also serves as an anchor for the holding member, thus eliminating the split ring which was formerly provided for this purpose. The clamp remains in position until it is desired to replace the tubes.

THORNHILL-CRAVER COMPANY

HOUSTON UNIBOLT REFINERY FITTINGS TEXAS

THE MONTH . . .

pure materials were invaluable as reference standards in many entirely new petroleum developments. He was director of the work being done at Penn State for American Petroleum Institute Research Projects 42, 43B, and 46 which were concerned with high molecular weight hydrocarbons, the origin of petroleum, and hydrocarbons for spectrometer calibrations, respectively. His work on the rearrangement of organic compounds was very important in the manufacture of special high octane super-fuels for military aircraft.

Since 1929 the Dean and his colleagues in the petroleum refining laboratory have been carrying out a comprehensive research program to help the Pennsylvania petroleum industry. As a result of this work more is known about the composition of Pennsylvania petroleum than any other crude oil. He was active in helping this industry obtain methods for characterizing and identifying Pennsylvania lubricants in order to protect the public from unfair trade practices. He was a vigorous proponent of applying scientific and technical developments to the efficient utilization of Pennsylvania petroleum. He guided the School's research and development work toward the modernization of the state's oil industry, the adaptation of new processes to the refining of Pennsylvania petroleum, and the use of chemicals and additives.

D. J. SMITH

D. J. Smith Elected Head Of Pan American Company

D. J. Smith has been elected president of Pan American Petroleum and Transport Company. C. H. Wagner was named head of the American Oil Company, Pan American's marketing affiliate.

The new executives were named to succeed E. G. McKeever, 55, who died July 9, and who had been president of both companies. Smith was formerly executive vice president of Pan American, and Wagner was vice president of and general manager of American Oil Company.

President of Pan American since 1945, McKeever's entire business career had been with that company or its predecessors. He joined Mexican Petroleum Corporation in 1915 and a year later participated in Pan American's organization. He was named a director in 1922 and first vice president in 1937.

Miller Joins Battelle

Cearcy D. Miller, mechanical engineer, has joined the staff of Battelle Institute, Columbus, Ohio. Miller, an engineer with the National Advisory Committee for Aeronautics for the past 11 years, is a graduate of George Washington University and a member of the Society of Automotive Engineers.

At Battelle, he will be engaged in research on automotive fuels. He has been active in this field for the past several years and is the author of papers on the subject.

Consumers Co-op Gives Up Agricultural Status

Consumers Cooperative Association, Howard A. Cowden, president, of Kansas City, Mo., which does a large oil business, has voted to relinquish its statutory exemption provided for qualifying agricultural co-ops under the internal revenue code, and by discontinuing payment of patronage refunds to nonmem-

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LONG-TIME PROTECTION

When you employ STOKES to paint or coat your equipment . . . whether it be a single tank, or a complete refinery layout, you are guaranteed a first-class job.

All surfaces are thoroughly cleaned — by sand blasting or bronze buffing before the paint or coating is applied. Save the Surface and You Save All. But remember — the surface must be clean before you cover it up. Address:

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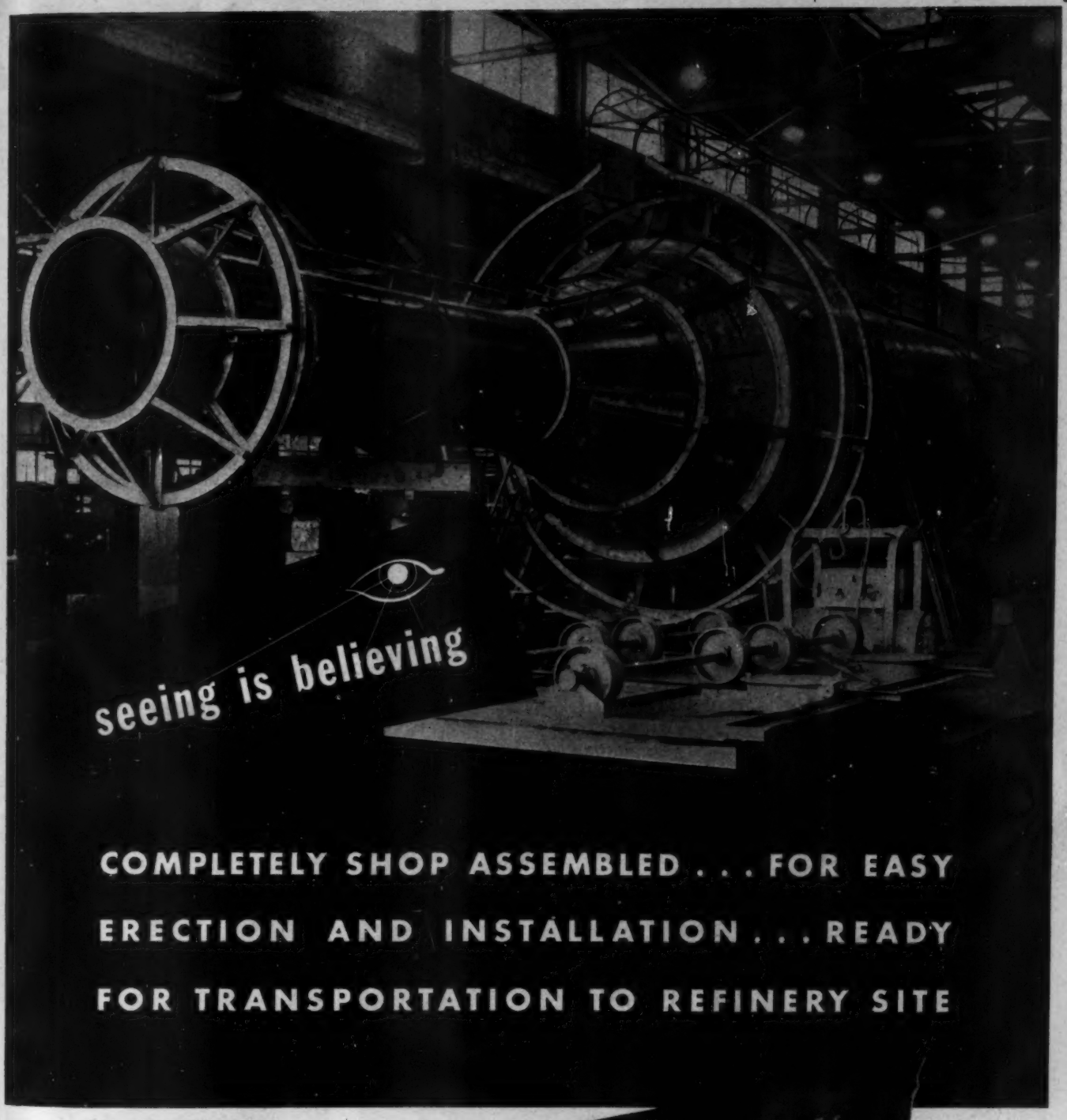

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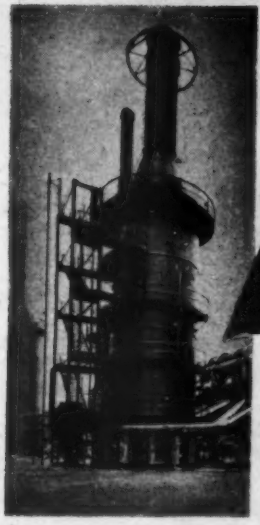

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UNLIMITED IN SIZE . . . CAPACITY . . . DUTY

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THESE EXCLUSIVE
AIRETOOL
FEATURES
SMASH TUBE-CLEANING COSTS

The Airetool P-type cleaning head mounted on a heavy duty refinery motor... air or steam driven... for straight tubes of 2¼" to 4¾" I.D.

• NEW FORM CUTTERS
Scientifically engineered . . . and proven by use-on-the-job . . . Airetool's new form cutters completely eliminate the danger of tracking or cutting tube walls . . . THEY CLEAN TUBES THOROUGHLY, QUICKLY AND SAFELY

• SLIP-FIT MOTORS
Slip-Fit construction of Airetool motors makes them easy to dismantle on the job without special tools . . . SAVES TIME!

• POWER SEAL
. . . stops power waste . . . assures maximum efficiency at all speeds. It maintains torque as low as 50 rpm without stalling.

• BALANCED ROTOR
. . . eliminates friction . . . directs all power against the load. Steam or air driven models.

• SPECIAL HEAT TREATMENT
. . . of alloy steel produces uniform grain and hardness in every working part . . . makes Airetool Tube Cleaners and Expanders last longer and cost less to operate.

• AIRETOOL EXPANDERS
Self-feeding and positive, built of finest heat-treated alloy steel. Made in every size . . . for every tube rolling and expanding requirement.

AIRETOOL
MANUFACTURING COMPANY
316 S. Center St.
SPRINGFIELD, OHIO

Write for bulletins on all types of Airetool refinery cleaners, expanders and accessories

THE MONTH...

bers, will pay income tax on such amounts retained by the corporation.

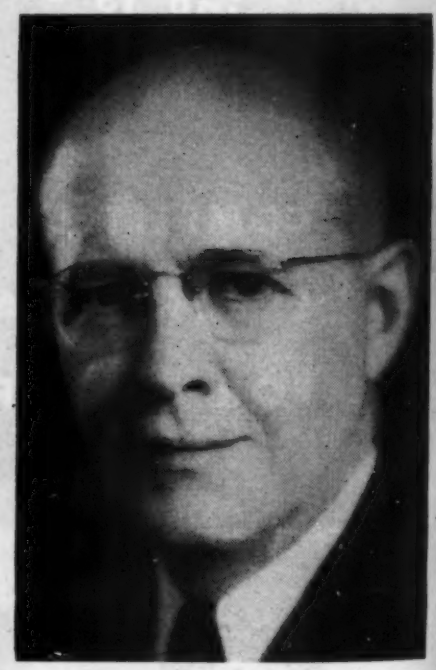
The change, effective September 1, does not mean the co-ops are running to cover in view of the congressional fight on co-op tax exemption, the directors declared. Two recent state Supreme Court decisions, one authorizing increase in capital stock from $2 to $12 million, granted CCA the right to carry out an industrial program in Kansas.

It has been announced that the House Ways and Means Committee will begin extensive hearings November 4 on tax-exempt privileges of co-ops.

Colvin Advances In Ethyl Staff at Baton Rouge

Charles E. Colvin has been appointed manager of the production planning section of the Ethyl Corporation plant at Baton Rouge, Louisiana. He succeeds B. E. Perkins, Jr., who has entered private business.

Colvin has been with Ethyl Corporation for 16 years, beginning in the Chicago office as a field representative. Since 1937 he has been assistant to John H. Shaefer, vice president in charge of manufacturing. In 1941 he served as manager of the technical division at Baton Rouge.



ROLAND V. RODMAN

Roland V. Rodman Heads Anderson-Prichard

Anderson - Prichard Oil Corporation has announced the election of Roland V. Rodman as president and a director of the corporation. L. H. Prichard, the former president, will continue as a director and has been elected chairman of the board.

Rodman, a native of Nebraska, was graduated from the University of Nebraska in 1919. After receiving his law degree from the same school he engaged in general law practice for eighteen

RY *Warehousing*

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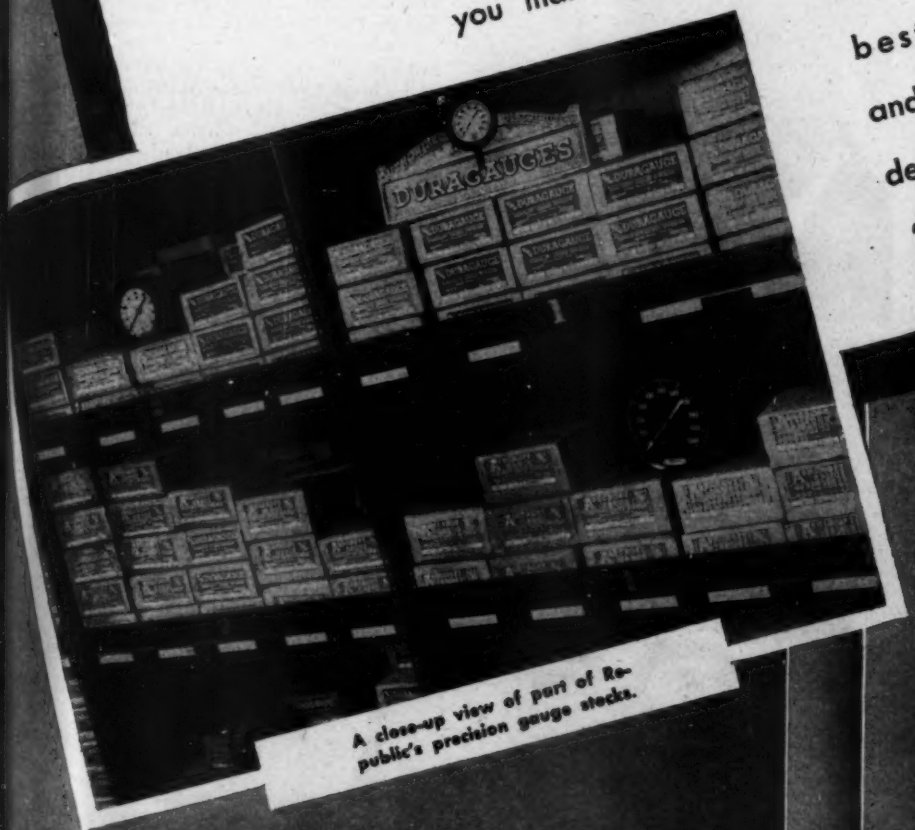
Makes your large inventory investments unnecessary—
Eliminates your costly accumulation of "dead" stocks—
Reduces your losses sustained from obsolescence—
Assures you proper stocks when and where they are needed—

● These are important advantages you enjoy when you make REPUBLIC your warehouse for refinery supplies. For everything best in refinery supplies and service you can depend on REPUBLIC. . . .

Your Supply Store



A close-up view of part of Republic's precision gauge stocks.

Republic Supply COMPANY

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FEATURES

SMASH TUBE-CLEANING COSTS

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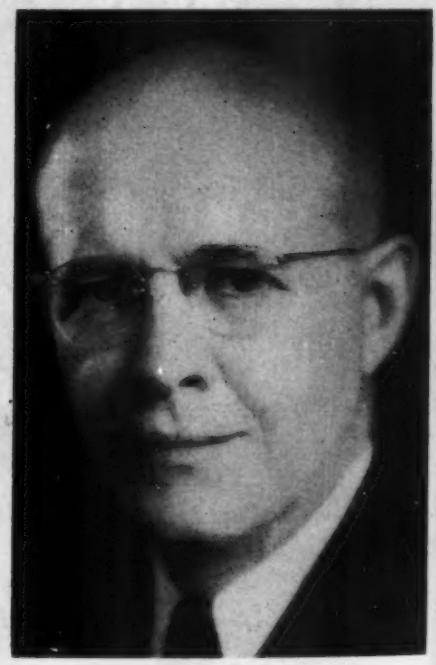

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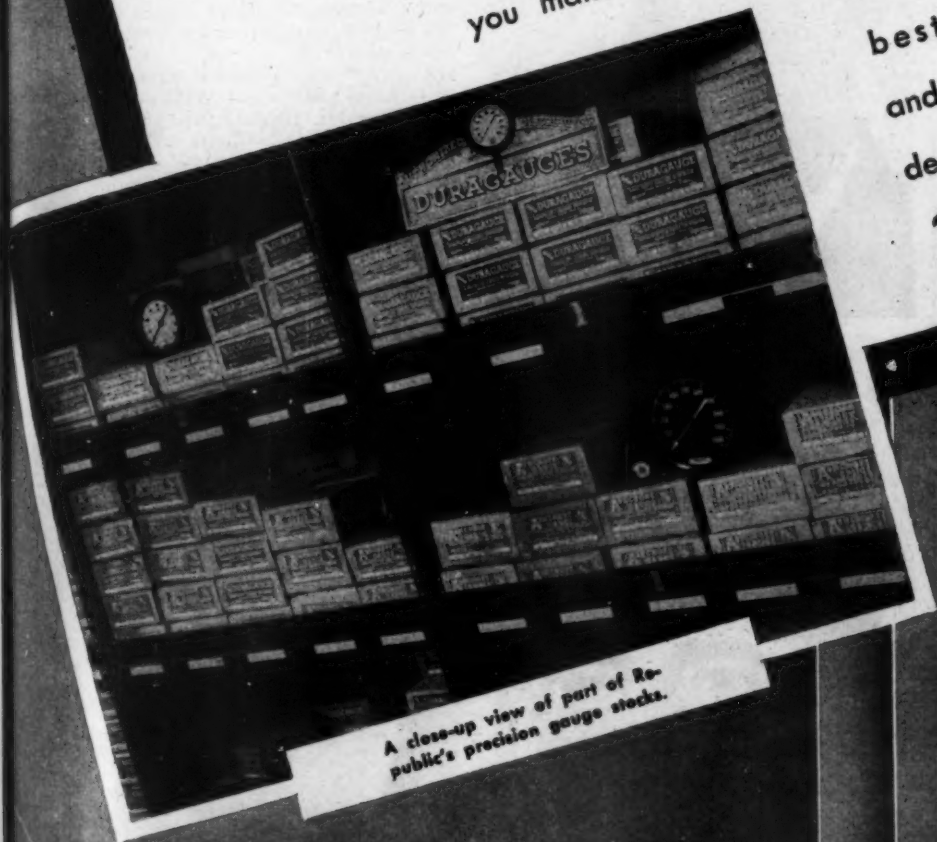

A close-up view of part of Republic's precision gauge stocks.

Republic Supply COMPANY

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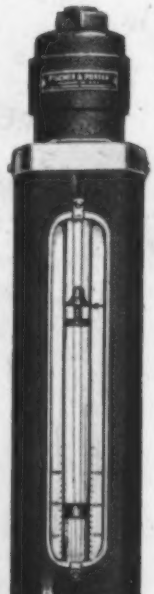
CONTINUOUSLY, AUTOMATICALLY (and with automatic control of the viscosity, if desired) RIGHT IN THE PIPE LINE, WITHOUT WITHDRAWAL OF FLUID SAMPLES, WITHOUT STOP-WATCH READINGS OF EFFLUX TIMES IS NOW AN ACCOMPLISHED FACT.

Viscosimeters have graduated from the class of laboratory test instruments to full-fledged industrial instruments which perform their function without manipulation by an operator, just as temperature, pressure, flow and level instruments have been doing for many years.

PRINCIPLE OF OPERATION

Continuous viscosimetry has been accomplished by utilizing one of the unique properties of the F & P FLOWRATOR meter (formerly rotameter): ability to make metering floats either viscosity sensitive or viscosity immune. Into one FLOWRATOR are placed two metering floats, the upper one so shaped that it is very viscosity sensitive, the lower one with the patented F & P viscosity immune shape. When fluid flows upward through the tapered metering tube both floats will, of course, rise in the normal manner. However, the elevation of the lower float will be relatively slight, since it is produced solely as a function of fluid flow rate. The upper float elevation will be much greater since it is function both of viscous drag and flow rate. The space increment thus created between the two floats is a direct measure of viscosity. By selecting any particular flow rate which will give a convenient elevation of the lower float to serve as a reference line, the upper float elevation may be marked off as viscosity graduations in terms of centipoises, centistokes, S.S.U. or any other desired units. The mathematics of this new viscosimeter have been fully worked out.



Write for catalog 88 giving much additional information. F & P FLOWRATOR CONTINUOUS VISCOSIMETERS have been thoroughly tested in trial installations operated for well over a year.

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DEPT. 7T-1C HATBORO, PENNA.

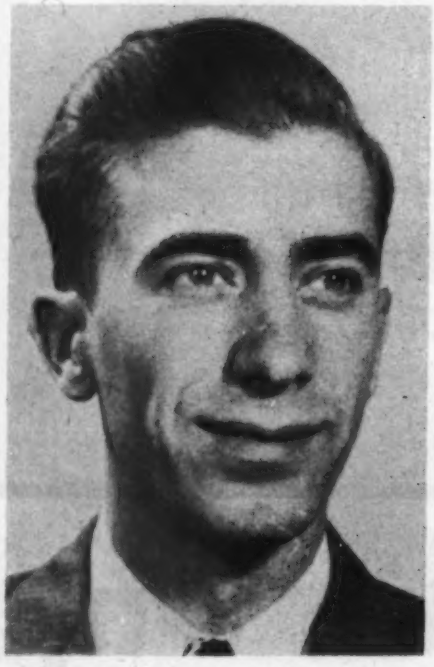
THE MONTH . . .

years. He became associated with The Bay Petroleum Corporation as general counsel in 1937, was made vice president and general manager in 1939, and was elected president in 1946.

The Bay Petroleum Corporation is engaged in the production, refining, and marekting of petroleum and petroleum products, having refineries in McPherson, Kan.; Denver, Colo., and New Orleans, and producing properties throughout the Mid-Continent.

Prichard is retiring as president of Anderson-Prichard Oil Corporation which he has served in that capacity since its organization in 1922.

R. N. GILES



WILLIAM F. MEEHAN

C. R. HARTE

Kay Elected President of Bay Petroleum Corporation

Gordon R. Kay, vice president of Bay Petroleum Corporation and Chalmette Petroleum Corporation, has been named president succeeding Roland V. Rodman. The new president, associated with Bay for 15 years, named a management committee of executives who were elected vice presidents. This group includes Charles O. Garbrecht, superintendent of manufacture. Complete revamping and enlargement of the company's refining facilities is planned, this program to be completed by late summer at both the Denver and McPherson plants. Facilities at the New Orleans refinery already have been increased.

U. S. Ambassador to Norway, Charles Ulrick Bay, will remain as chairman of the company's board.

Promotions Announced by Standard of Indiana

R. N. Giles, superintendent of technical service in the Whiting, Ind., laboratories of Standard Oil Company (Indiana), has been promoted to director of technical service with headquarters in the research department at the general office in Chicago. He will be responsible for direction of technical service activities at all of the Standard of Indiana refineries. Dr. Giles joined Standard Oil in 1930 after graduate work at Ohio State university.

C. R. Harte, assistant superintendent of technical service at Whiting, succeeds Dr. Giles. Dr. Harte joined the company in 1936, after graduate work at the University of Michigan and several years of subsequent experience in industry.

W. F. Meehan, a group leader, was advanced to fill the post vacated by Dr. Harte. Mr. Meehan became associated with Standard in 1942 following graduation from the University of Detroit. R. S. McDaniel succeeds Mr. Meehan.

E. B. Tucker has been appointed section leader in charge of a newly organized research analytical section of

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the Whiting laboratories. H. M. Grubb and W. L. Rittschof have been made group leaders in this section. F. W. Porsche has been made foreman of the gas analyses laboratories, succeeding Mr. Rittschof.

G. W. Flint has been advanced to section leader in charge of work on specialties. C. E. Adams has been appointed section leader in charge of exploratory research on chemical products. E. J. Campau, A. W. Lindert, D. E. Burney, Philip Hill, W. R. Hertwig, and Moses Gordon have been made group leaders. Michael Dufinecz is appointed patent advisor assisting J. C. Stauffer.

Socony-Vacuum Names Teitsworth A Director

Clark S. Teitsworth, General Petroleum's supervisor of process laboratories prior to his transfer to Socony-Vacuum, New York, in 1934, for work on catalytic cracking, has been elected to the latter company's board of directors. He has been chairman of the company's manufacturing committee and will continue to supervise company refining and research.

Teitsworth, a native of Minneapolis, was graduated from Stanford University in 1919 with a degree in chemical engineering and did graduate work at the University of Minnesota and the California Institute of Technology. He joined General Petroleum, a Socony-Vacuum affiliate, in 1926. He has been intimately associated with the development and commercialization of catalytic cracking since transferred to New York.

Next ASTM Convention Scheduled at Detroit

The 1948 annual meeting of the American Society for Testing Materials will be held June 21-25 in Detroit and in conjunction therewith will be the 8th exhibit of testing apparatus and related equipment. Headquarters will be at the Book-Cadillac.

The 1948 Committee Week and spring meeting will be held in Washington March 1-5, according to T. A. Boyd, fuel department, Research Laboratories Division, General Motors Corporation, Detroit, elected president of ASTM at the 50th annual meeting held recently in Atlantic City.

J. G. Morrow, Metallurgical Engineer, Steel Company of Canada, Ltd., Hamilton, Ontario, Canada, is the new vice president to serve with the Senior Vice President R. L. Templin, assistant director of Research and chief engineer of tests, Aluminum Company of America, New Kensington, Pa.

Immediate past president Arthur W. Carpenter, manager of testing laboratories, The B. F. Goodrich Company, Akron, Ohio, will continue on the board of directors for three years.

New Record Set at Linden In Cat Overhauling Job

A record overhauling job was finished in July on a Fluid catalytic cracking unit at the Linden, N. J., refinery of Standard Oil Company of New Jersey.

By completing in 14 days a servicing job that had never before been performed at the plant in less than 21 days, repair crews enabled the unit to pick up an extra week of output over the year. Translated into products, this represents extra output of 3 million gallons of gasoline and 2.5 million gallons of heating oil that otherwise could not have been manufactured.

Refinery superintendent J. R. Eiffe, crediting teamwork between mechanical workers and supervisors for the record-breaking performance, said that in the face of the present temporary tightness of supply in petroleum products, the employes determined at a conference to do everything possible to reduce the time of the overhaul period. This periodic repair work on the 250-foot "cat cracker," which has a capacity of 20,000 barrels a day, is necessary every six to eight months.

Innovations devised to speed the job included a public address system installed throughout the structure to allow a job coordinator to give directions without having to send messengers to various parts of the 20-story unit.

Sound-powered phones, used by the

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

(All figures in thousands of barrels—add 000)

Trends in Week Ended	Crude Oil			Gasoline		Gasoil and Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1946:									
January 26	4,626	4,553	220,544	13,622	101,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	224,994	13,896	104,715	5,337	28,240	8,738	37,746
April 27	4,672	4,685	224,443	14,228	99,631	5,568	30,466	9,204	39,404
May 25	4,759	4,857	222,214	14,322	95,769	5,463	32,973	8,908	43,368
June 29	4,957	4,854	223,883	14,500	92,333	5,325	37,762	8,828	46,447
July 27	4,926	4,896	223,756	14,535	88,626	5,817	44,316	8,217	49,517
August 24	4,836	4,866	225,672	14,639	86,251	5,649	51,405	8,126	52,061
September 28	4,778	4,829	221,903	14,538	85,854	5,450	57,903	8,158	56,914
October 26	4,730	4,758	221,184	14,863	84,623	5,710	65,499	7,728	60,872
November 30	4,795	4,707	225,119	15,145	88,371	5,228	66,062	7,672	58,847
December 28	4,713	4,968	226,111	15,604	93,126	5,931	58,941	8,181	53,427
1947:									
January 25	4,672	4,820	221,655	14,624	99,801	5,630	50,357	8,224	48,556
February 22	4,786	4,860	224,580	14,668	103,904	5,929	40,739	8,532	44,919
March 29	4,865	4,843	225,720	14,396	107,576	5,969	32,737	8,668	43,364
April 26	4,930	4,725	234,051	14,213	103,860	5,435	32,286	8,186	42,668
May 31	5,024	5,000	239,370	14,709	95,876	5,732	36,032	8,910	45,224
June 28	5,109	5,093	236,221	16,070	91,806	5,606	41,721	8,298	48,490
July 26	5,084	5,162	231,357	16,142	85,812	5,708	47,097	8,738	52,497

THE MONTH...

fuel department. Along with Charles F. Kettering and Thomas Midgley, Jr., he was a co-discoverer of tetra-ethyl-lead as an anti-knock agent.

ROBERT F. CARTER

Lummus Superintendent Gets Association Post

Robert F. Carter, general construction superintendent of The Lummus Company, New York, has been elected vice president of the National Construction Association.

Previous to his work with the Lummus organization, Carter was a consultant in construction. With the company he has filled positions as operator, job engineer and superintendent on both domestic and foreign construction in the refining field.

His promotion to general superintendent was recent and in it he will have charge of all construction for the company.

Hazards of Air-Isobutane Mixtures Cited in Bulletin

Explosion hazards of mixtures of air and isobutane have been successfully eliminated through introduction of certain inert gases, according to a new Bureau of Mines report describing the results of a lengthy study. Either nitrogen or carbon dioxide may be used to render the atmosphere inside an isobutane storage tank free of explosion dangers when making repairs involving welding, the report points out.

Bureau tests to determine ignition and explosion hazards of isobutane proved that when 39.9 percent of nitrogen or 26 percent of carbon dioxide was added to an isobutane-air mixture, the mixture became noninflammable.

A table showing the amount of inert gas needed to render other combustible-air mixtures noninflammable also is included. In most cases, this may be accomplished by adding at least 35 percent of carbon dioxide or 47.5 percent of nitrogen to the combustible gas-air mixture, the report states.

Physical and chemical properties of isobutane, limits of inflammability in air; minimum ignition temperatures, and the preventon of isobutane-air explosions by oxygen control are other topics covered. The report was prepared by G. W. Jones and G. S. Scott, Bureau chemists with the Gaseous Explosions Section, Explosives Division, Central Experiment Station, Pittsburgh, Pa.

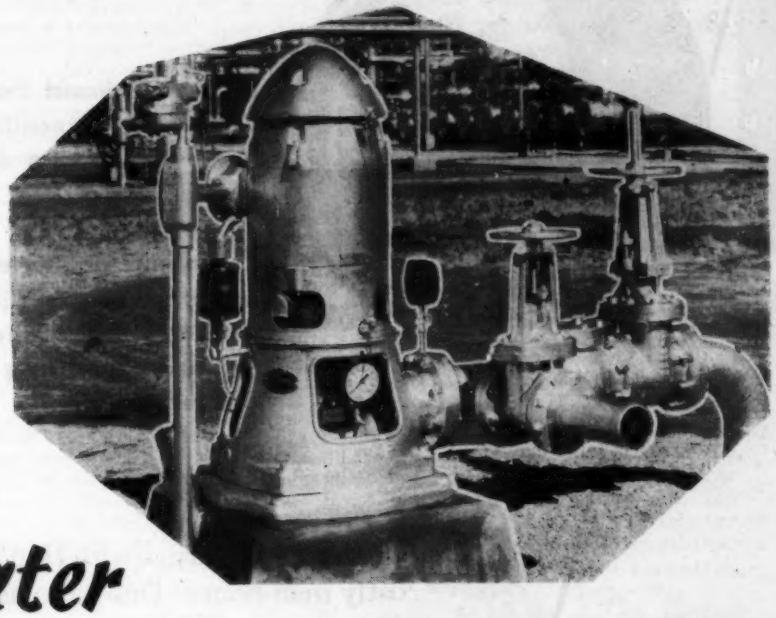
A copy of Report of Investigations 4095, "Extinction of Isobutane Flames by Carbon Dioxide and Nitrogen," may be obtained free from the Bureau of Mines, Department of the Interior, Washington 25, D. C.

Officers Are Elected by California Meter Group

Officers for the 1947-1948 term of the Southern California Meter Association have been named as follows:

President, Curtis G. Cortelyou, General Petroleum Corporation; vice president, J. C. Groenewegen, Shell Chemical Corporation; secretary-treasurer, Geo. H. Forster, Jr., 2916 Eucalyptus Avenue, Long Beach; auditor, J. Andrew Waltman, Southern California Gas Company; past president, Lee Cheever, Southern Counties Gas Company.

Chairmen of committees follow: Program, C. S. Beard, Southern California Gas Company; entertainment, James Gesner, Reliance Regulator Corporation; membership, W. Frank White, Southern



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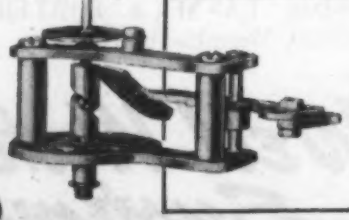

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THE MONTH...

California Gas Company; publicity, Merrill Berkley, Berkley Engineering & Equipment Company; standards, J. A. Till, Southern California Gas Company; by-laws, James E. Adams, Signal Oil & Gas Company; instrumentation, Lawrence B. White, Wilshire Oil Company; San Joaquin Valley, Ross T. Furlong, The Texas Company.

Chemical Engineering Symposium in December

Progress in the field of heat transmission will be discussed at the fourteenth annual chemical engineering symposium of the American Chemical Society scheduled in Chicago, December 29-30. Dr. Lincoln T. Work of Metal and Thermit Corporation, Rahway, N. J., is chairman of the symposium committee of the society's division of Industrial and Engineering Chemistry, which will sponsor the event.

The technical program is being planned by a subcommittee headed by Professor Thomas Drew of Columbia University and authors desiring to submit papers should communicate with him. Professor Robert Kintner of the Illinois Institute of Technology is chairman of a Chicago committee in charge of local arrangements.

Francis J. Curtis, vice president of Monsanto Chemical Company, St. Louis, is chairman of the Industrial and Engineering Division of the Society, and Dr. William A. Pardee of Gulf Research and Development Company, Pittsburgh, is secretary-treasurer.

Western Natural to Build Texas Recycling Plant

Western Natural Gas Company, Paul Kayser, president, has announced that it plans to install a small recycling plant on properties recently purchased in Live Oak and Bee counties, Texas. Tracts involved in the purchase, designed to increase the company's gas reserves, total 8000 acres producing and 16,000 acres wildcat territory.

Kayser has announced that Western Gas Company, El Paso, has been merged into his company the name of which has been changed from Gulf States Oil Company to Western Natural Gas Company, a Delaware corporation, with headquarters in Houston.

Kellogg's Backlog of Orders Reveals Big Gain

A gain in three months of $20 million in the company's backlog of unfilled construction projects is revealed in a report made by H. R. Austin, president of The M. W. Kellogg Company, engineers and fabricators of Jersey City, N. J., and New York, N. Y. The backlog at the end of the first quarter, 1947, was $80 million whereas at the end of June 30, a backlog of more than $100 million was reported.

"The present modernization and expansion program of the oil refining industry, which is the most expansive ever undertaken by that major division of our economy, is advancing," Austin said. "While it will take far more than a

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single year's work to meet the needs of an industry, which, like the rest of American industry, could do little or no basic improvement during the five war years, the current steps being taken in that direction are both comprehensive and significant."

The company's commitments and the industrial outlook point toward increased activity of service in many industries for the remainder of 1947 and 1948, Austin said, concluding:

"Industry is entering its full cycle of peacetime operation. Its equipment demands, embracing the three divisions of normal replacement, expansion, and improvement, are urgent and extensive. Material shortages, as stated, impeded construction to an appreciable degree in the first half. With the hoped-for alleviation of that problem, we can look forward to a period of balanced and vigorous activity through the remainder of the year."

Adjunct to ASTM Book on Standards Now Available

Copies of the American Society for Testing Materials "Index to A.S.T.M. Standards," as of December, 1946, but published in June, 1947, are now available without charge upon written request to ASTM headquarters, 1916 Race Street, Philadelphia 3.

This 242-page publication is really an adjunct to the 1946 Book of Standards and enables any of the some 1400 standard specifications and tests in the volumes to be located readily. The Index is also of service to those who wish to determine whether ASTM has issued standard specifications, test methods, or definitions covering a particular engineering material or subject.

All items are listed in the Index under appropriate key-words according to the particular subjects they cover. As a convenience a list is given of the specifications and tests in numerical sequence of their serial designations.

Operations Begin at Louisiana Cycling Plant

Operation of the unitized cycling plant, serving the Lake St. John field in Tensas and Concordia parishes was begun in July with the California Company as operator. The unit is unique in that both oil production as well as the products recovered in the cycling plant are under one plan of operation.

The plant has capacity for handling 100,000,000 cubic feet of gas daily. Absorption will be accomplished at 1600 pounds and the dry gas injected back into the producing formation at 4000 pounds. Crude oil, condensate, butane and propane are the products covered by the plan, which provides that each owner share in proportion to the value of recoverable reserves under his tract.

Stone & Webster's War Record Pictured in Book

Through the book "A Report to the People," Stone & Webster Engineering Corporation, New York, has portrayed the part that it had in the winning of the war. It is not a technical treatise on the design and construction of the war plants that were built by Stone & Webster from the time of Pearl Harbor to Hiroshima, but a simple pictorial story that any person would enjoy reading. The illustrations are actual photographs of the various plants in which the ammunition and other products were manufactured. One of the most vital of these plants was the one constructed at Oak Ridge, Tenn., for the manufacture of the atomic bomb. Letters of commendation from the War Department to Stone & Webster are many, because of the tasks the company performed in the manufacture of vital products used in winning the war.

LPG Tankers Turned to Trade in South America

Standard Oil Company (New Jersey) has converted the steamship, Esso San Paulo, to handle liquefied petroleum gas in bulk on a regular run between Aruba, Rio de Janeiro and Santos, Brazil. It will also carry part cargoes of other petroleum products.

Standard plans a small fleet to carry propane to South America. The steamer Esso Avila is currently being converted and will carry lpg to Venezuela and Central America.

Aurora Plant on Stream

The fluid catalytic cracking unit in the Aurora Gasoline Company's refinery at Detroit, designed and licensed by Universal Oil Products Company, has been brought on stream.

This unit is the first to be placed in operation embodying design features which include a single column reactor-regenerator structure which eliminates the structural steel used to support the reactor-regenerator in earlier designs.

The charge stock is 28-gravity Illinois gasoil and microspherical silica-alumina catalyst is being used.

Interior Appropriations

The Interior Department appropriation bill, as finally passed by both the Senate and the House of Representatives, carried $3 million (instead of the $5 million requested by President Truman) for synthetic liquid fuels research and experiment.

The Oil and Gas Division, originally turned down by the House, was given $275,000, including $100,000 for coordinating and unifying federal petroleum activities.

O'Bryan Dies

James Finley O'Bryan, 56, Tulsa, processing superintendent for the Mid-Continent Petroleum Corporation refinery, died July 16 in Tulsa. A native of Bardstown, Ky., O'Bryan was employed by Standard Oil Company at Neodesha, Kan., for nine years before moving to Tulsa in 1918.

Henry Greis Dies

Henry N. Greis, 67, president of Deep Rock Oil Corporation and Burke-Greis Corporation, died in Tulsa July 16. He had been in failing health for some time.

Greis was a native of Buffalo, N. Y., but had lived in Tulsa since 1909. He was a graduate of the U. S. Military Academy at West Point.

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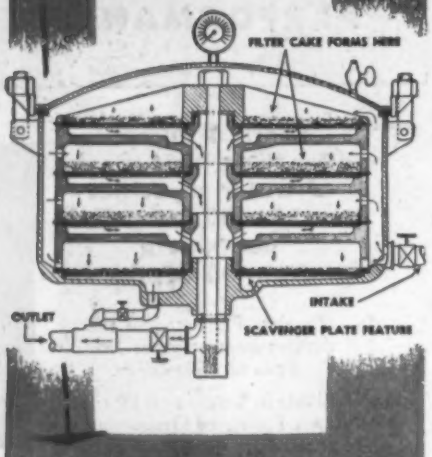

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Higher Demand for Petroleum Products Are Indicated by Revised Forecasts

L. J. LOGAN

IN 1947 AS IN 1946, it has been necessary to increase original estimates of the demand for petroleum products, and the latest figures of the Bureau of Mines, as of June 1, forecast a 7.7 percent increase over 1946 in the total demand for all oils. This estimate still is a good guide, although current trends and circumstances are variously interpreted as calling for upward or downward revision.

In publishing this revised forecast, the bureau significantly pointed out that "Demand has reached such high levels that the forecast represents more nearly the probable supply of refined products available than the potential ability to consume oil. The limiting factor is refinery capacity." The forecast also made mention of the fact that local shortages in oil supply had resulted from limitations in pipe line capacity and lack of available tank cars.

Since the report was issued, the demand for gasoline in the Middle West has had a ceiling placed over it through company allocations of supplies to dealers, and heating oils might have been moving in somewhat larger volume if more supplies were available. Thus, the limitations on demand in the form of inadequate refining and transportation facilities already are being demonstrated as foreseen by the bureau.

Marginal Refining Capacity

However, there is a substantial amount of existing marginal refining capacity—as much as several hundred thousand barrels daily—which normally would remain idle because of being inefficient and expensive to operate, but which can be operated. In the present tight supply situation, this utilization of inefficient refining capacity may assume important proportions and result in the actual fulfillment of demand in excess of the above estimate for the year, al-

Revised Forecast, United States Supply and Demand, All Oils, 1947, By Quarters

(Source: Bureau of Mines Monthly Petroleum Forecast, June, 1947)
(THOUSANDS OF BARRELS)

ITEM	First Quarter (Actual)	Second Quarter	Third Quarter	Fourth Quarter	1947 Year	1946 Year	Percent Diff. '46-'47
Domestic Production:							
All Oils	463,300	486,000	489,000	489,400	1,927,700	1,850,700	+ 4.2
(Daily Average)	5,148	5,340	5,315	5,320	5,282	5,070	.....
Crude Oil	431,700	453,200	455,400	455,400	1,795,700	1,733,400	+ 3.6
(Daily Average)	4,796	4,980	4,950	4,950	4,920	4,749	.....
Other Oils	31,600	32,800	33,600	34,000	132,000	117,300	+12.5
(Daily Average)	352	360	365	370	362	321	.....
Imports:							
All Oils	43,400	43,400	44,100	45,100	176,000	135,000	+30.4
(Daily Average)	482	477	480	490	482	370	.....
Crude Oil	25,400	25,700	26,000	26,000	103,100	86,100	+19.7
(Daily Average)	282	282	283	283	282	236	.....
Other Oils	18,000	17,700	18,100	19,100	72,900	48,900	+49.1
(Daily Average)	200	195	197	207	200	134	.....
Change in Stocks:							
All Oils	—26,100	+18,600	+23,300	— 4,500	+11,300	+43,500	.....
(Daily Average)	— 289	+ 204	+ 254	— 49	+ 31	+ 119	.....
Crude Oil	+ 4,800	+11,800	— 3,700	— 1,800	+11,100	+ 6,900	.....
(Daily Average)	+ 54	+ 130	— 40	— 20	+ 30	+ 19	.....
Other Oils	—30,900	+ 6,800	+27,000	— 2,700	+ 200	+36,600	.....
(Daily Average)	— 343	+ 74	+ 294	— 29	+ 1	+ 100	.....
Demand:							
All Oils	532,800	510,800	509,800	539,000	2,092,400	1,942,200	+ 7.7
(Daily Average)	5,919	5,613	5,541	5,859	5,733	5,321	.....
Motor Fuel	180,600	215,000	225,000	205,000	825,600	780,200	+ 5.8
(Daily Average)	2,007	2,363	2,446	2,228	2,262	2,138	.....
Residual Fuel	140,200	124,000	117,000	130,000	511,200	486,600	+ 5.1
(Daily Average)	1,557	1,363	1,272	1,413	1,401	1,333	.....
Distillate Fuel	101,700	66,000	56,000	87,000	310,700	272,300	+14.1
(Daily Average)	1,130	725	609	946	851	746	.....
Kerosine	35,400	22,000	20,000	33,000	110,400	97,700	+13.0
(Daily Average)	393	242	217	359	302	268	.....
All Other	74,900	83,800	91,800	84,000	334,500	305,400	+ 9.5
(Daily Average)	832	920	997	913	917	836	.....
Crude Requirements:							
Runs to Stills	432,000	443,800	460,000	460,000	1,795,800	1,730,100	+ 3.8
(Daily Average)	4,800	4,875	5,000	5,000	4,920	4,740	.....
Demand for Domestic Crude	428,130	440,765	459,080	457,240	1,785,215	1,727,545	+ 3.3
(Daily Average)	4,757	4,845	4,990	4,970	4,891	4,733	.....

NOTE:—This revised forecast for the second quarter is based, in part, on current data available for April and May. Imports have been projected for the year at the daily average rate for the first quarter. The demand for domestic crude oil may vary with changes in the import rate of crude petroleum or with the amount of crude that can be run to stills. The estimated demand for all oils is primarily a matter of the supply of products as limited by available refinery capacity.

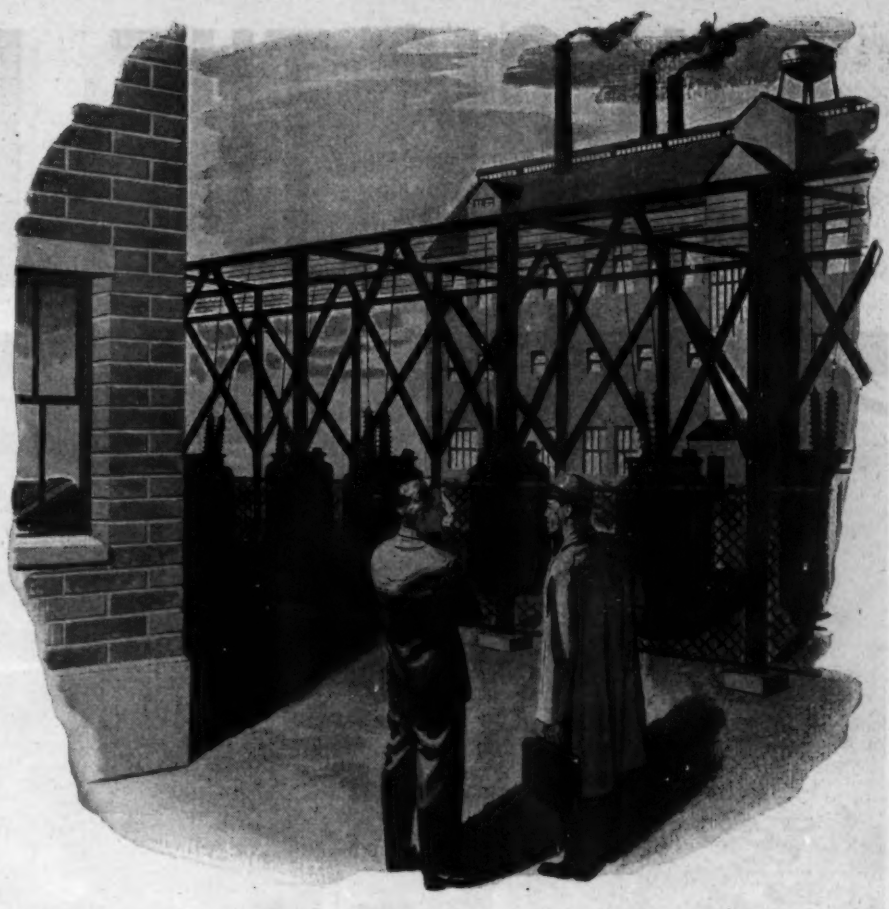
though the special measures in refining also necessitate corresponding extraordinary efforts in transportation of oils.

In view of recent trends of refinery runs and crude production at record levels, there are now some indications that the industry will succeed in providing supply in volume very close to potential demand; that more demand will be satisfied than the above forecast anticipated. As demand has become more insistent, efforts of the industry have been intensified. In the determination to do everything possible to satisfy the needs of their customers, many oil companies are resorting to various extraordinary measures in refining, transportation, and production. While the Bureau of Mines forecast assumed a limit of 5 million barrels per day on refinery runs for both the third and fourth quarters of 1947, the industry actually ran to stills an average of more than 5,100,000 barrels daily in June, and a prominent oil company executive estimated that a rate of 5,200,000 daily could be maintained consistently, through utilization of marginal refining capacity. Crude production, while crowding maximum efficient rates in nearly all areas, is a somewhat lesser problem, and has been kept abreast of refinery requirements. Although the forecast on the basis of refinery runs of 5 million barrels daily called for domestic crude production of a little less than 5 million barrels per day, output actually was maintained at the rate of approximately 5,100,000 daily during June.

Demand Prospect

While the discussion above assumes continuance of demand in volume hard to satisfy, there is a possibility that the potential demand may not prove so great as some observers anticipate. It is true that the total demand for all oils in the first quarter of 1947 broke all records for the season and was 12.6 percent greater than in the corresponding period of 1946. But data for later months indicated smaller increases over 1946, beginning with a 9.7 percent increase for April. The view has been expressed that first-quarter indicated demand may have been substantially greater than actual consumption because of purchases for secondary storage by marketers, expecting scarcity and higher prices. Demand as calculated by the Bureau of Mines reflects changes in stocks at refineries and bulk terminals but not beyond those primary storage points. In view of operating statistics following the first quarter, some economists began to think that petroleum products demand for the year as a whole might not be materially greater than originally expected.

In its June revision of its forecast for 1947, the Bureau of Mines calculated



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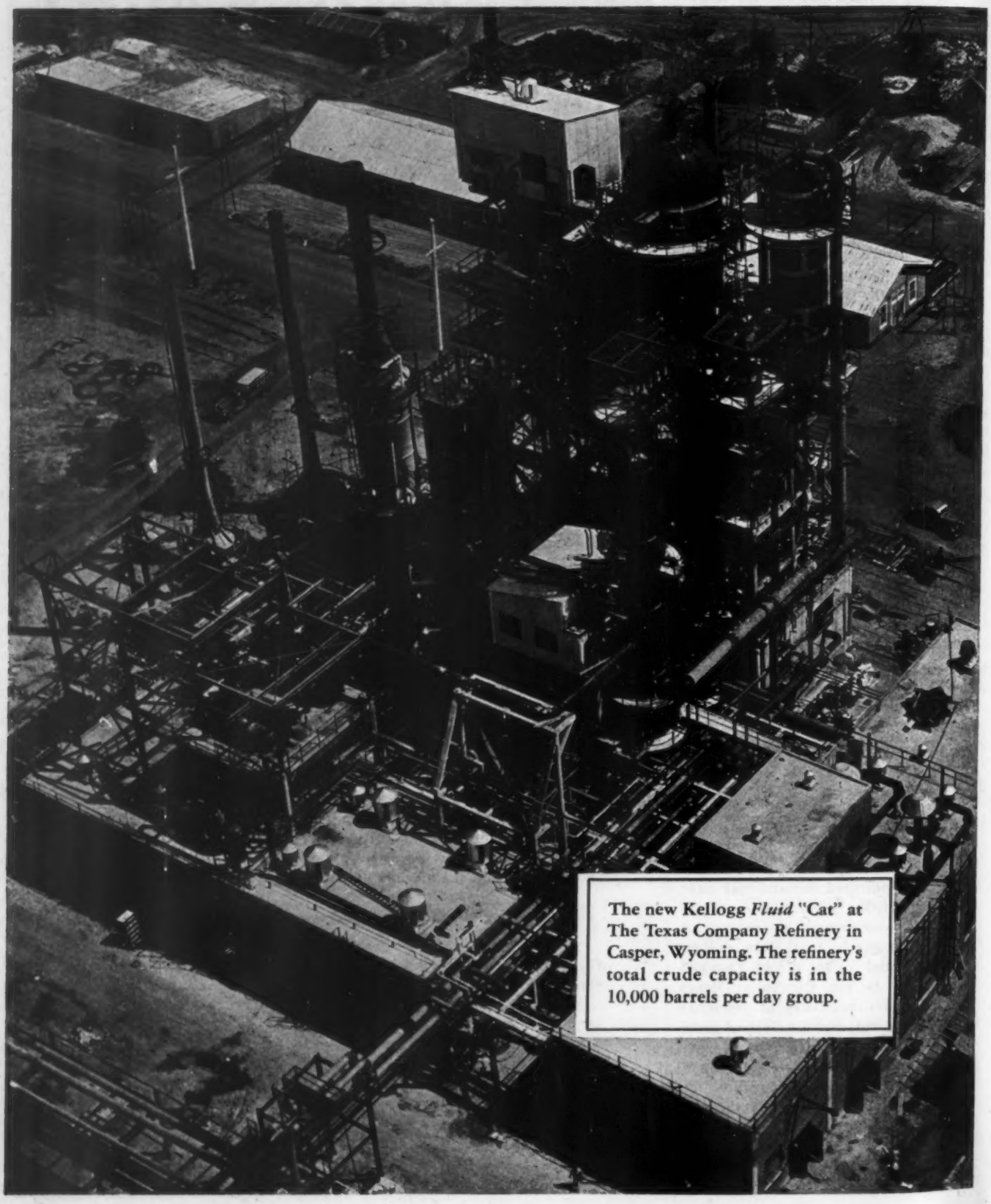

The new Kellogg *Fluid* "Cat" at The Texas Company Refinery in Casper, Wyoming. The refinery's total crude capacity is in the 10,000 barrels per day group.

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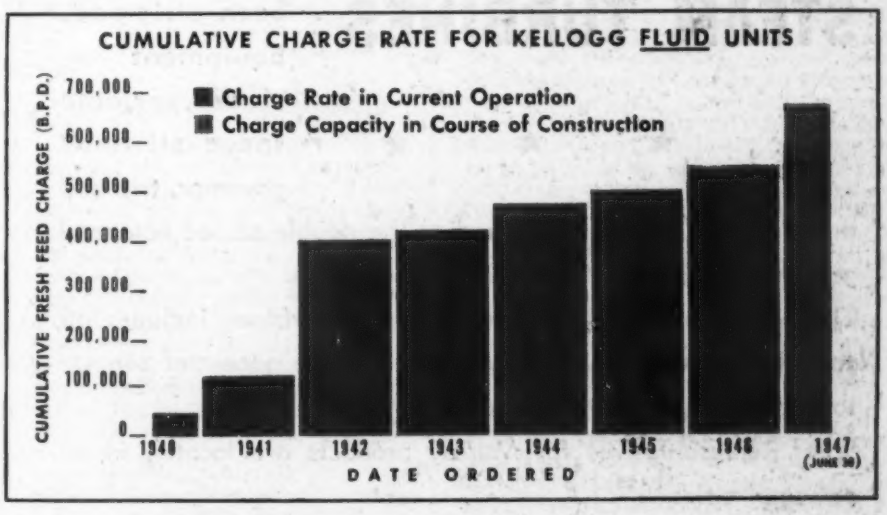
3 HIGHEST EARNING POWER is the direct result of the flexibility, efficiency and economy of the Kellogg *Fluid* "Cat" . . . adaptable to big or little refineries, alike. Kellogg *Fluid* "Cats" are operating in refineries where the total crude capacity runs less than 10,000 BPD — as well as in some of the world's largest plants.



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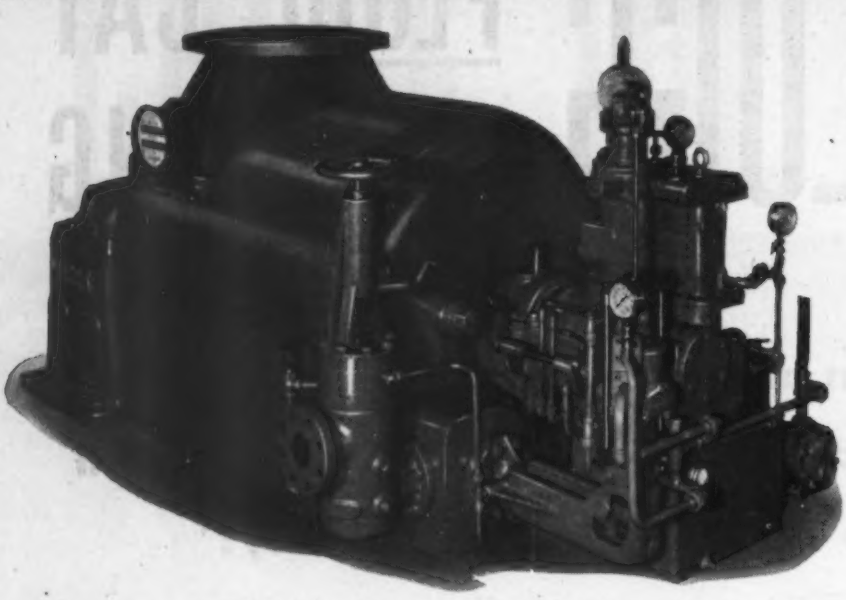

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that for 1947 the total demand for all oils would average 5,733,000 barrels daily, an increase of 7.7 percent over the 5,321,000 daily recorded for 1946. This was the second time that the Bureau revised its forecast for 1947. The original forecast was made in December, 1946, and contemplated an increase of 4.3 percent in total demand for all oils in 1947. The first revised forecast was made in April, 1947, and estimated that the increase would be 6.2 percent. The second revised forecast, published in June, raised the estimated increased to 7.7 percent.

Original estimates of demand have been increased for all of the principal products, and the sharpest revisions have been those for distillate fuel oil and kerosine, now expected to show 1947 gains of 14.1 and 13.0 percent, respectively. The unprecedented demand for these heating oils reflects a very high percentage of oil burners installed as heating equipment in the new homes that are being constructed and also numerous installations in older homes, in getting away from coal. Similar trends are expected to continue into the future.

The latest forecast places motor fuel demand for this year 5.8 percent above last year, a materially larger gain than previously estimated. Accelerated production of automobiles, trucks, and busses partly accounts for the increased estimate, and another factor is the continued use of more older vehicles than expected. Non-automotive consumption is meeting or exceeding earlier expectations.

This year's demand for residual fuel oil now is estimated 5.1 percent above 1946. Originally, little if any gain was expected, mainly because it was doubted that supply in excess of 1946 would be available. Increased imports have provided additional supply, but the possibility remains that some of the potential demand will not be fulfilled.

Shell to Enlarge Ammonia Production

Shell Chemical Company will double the size of its synthetic ammonia plant at Shell Point, near Pittsburgh, California. The work will be completed within a year. This plant, largest in the west, has been enlarged once since the end of the war.

New Tanker Terminal

A 500,000-barrel deepwater tanker terminal will be built by Standard Oil Company of New Jersey on the Cape Fear River below Wilmington, N. C. Work is tentatively scheduled to start next year. A dredging program, currently under way, will make the plant accessible to the largest tankers.

Standard has acquired a 60-acre tract south of the Socony-Vacuum's terminal.

SCIENCE AND TECHNOLOGY ABSTRACTS

prepared in cooperation with

PETROLEUM REFINER

by

THE LESLIE LABORATORIES

Traver Road, Ann Arbor, Michigan
under supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

The Heat Capacities, Heats of Fusion and Entropies of the Six Pentenes. SAMUEL S. TODD, GEORGE D. OLIVER AND HUGH M. HUFFMAN, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1519-25.

As a continuation of the program of the Bureau of Mines to obtain systematic thermodynamic data on hydrocarbons and related compounds, low-temperature calorimetric studies were made on the six pentenes over the temperature range 12 to 300° K. Data on the melting points are presented in tabular form. Data on the molal heat capacities of the pentenes are given in considerable detail in tabular form. Molal heat capacities at integral temperatures are tabulated and the molal heats of fusion are given in tabular form. Molal entropies of the pentenes were calculated.

Nomograph for Flash Vaporization. MELVIN NORD, *Anal. Chem.* **19** (1947) pp. 431-2.

In the calculation of flash vaporization problems, for multi-component systems, tedious trial-and-error solutions are required. The time required for the calculations is out of proportion to their value, if one wishes to evaluate the entire flash vaporization curve. The author presents a nomographic method that simplifies the calculations.

Ternary Systems n-Butane-1-Butene-Furfural and Isobutane-1-Butene-Furfural. J. A. GERSTER, T. S. MERTES AND A. P. COLBURN, *Ind. and Eng. Chem.* **39** (1947) pp. 797-804.

Vapor-liquid equilibrium data are presented for representative ternary systems encountered in the separation of the C_4 hydrocarbons by extractive distillation. The components of the two ternary systems studied are n-butane, 1-butene, and furfural, and isobutane, 1-butene, and furfural. Binary equilibrium data of the same hydrocarbons separately with furfural were reported in a previous paper. The flow-type apparatus utilized in the binary studies required only slight modification so that reproducible ternary data could be obtained. Vapor-liquid relations were determined at pressures up to 100 pounds per square inch, at temperatures of 100, 125°, 150°, and 200° F., and at varied concentrations of hydrocarbon. The results, corrected for nonideality of gases and volume of liquid, are presented as activity coefficients of each hydrocarbon component and as values of relative volatility as functions of composition. Ternary van Laar equations employing constants from the binaries apply quite well to this system, three-suffix Margules ternary equations agree with the experimental data when the ternary constant is evaluated. Increasing temperature lowers the activity coefficients in line with the results on the binary systems and also lowers the values of relative volatility. Combination of experimental data and theoretical equations permit the establishment of the effects of major variables on relative volatility and, therefore, on the economic operation of extractive distillation columns utilizing this mixture. The data are presented in considerable detail in tabular and graphical form. A bibliography of 11 references is included.

Heats of Polymerization. III. Styrene and Substituted Styrenes. L. K. J. TONG AND W. O. KENYON, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1402-5.

The isothermal calorimeter shows a small heat loss that is significant when monomers that polymerize slowly are to be studied in it. A method of determining and correcting for the heat loss is described, The apparent heats of polymerization of styrene and the substituted styrenes were measured and found to increase linearly with the catalyst concentration. Extrapolation of the apparent heat of polymerization-catalyst concentration curves to zero catalyst concentration was used to give values of $-\Delta H$ as k.cal./mole. The dependence of $-\Delta H$ upon catalyst concentration is suggested as caused by unknown side reactions, possibly involving oxidation. The data are presented in tabular and graphical form.

Solid Solution Studies. I. Equilibria in the Binary Systems, 2,2-Dimethylbutane-2,3-Dimethylbutane and 2,2-Dimethylbutane-Cyclopentane. H. L. FINK, M. R. CINES, F. E. FREY AND J. G. ASTON, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1501-6.

Liquid-solid equilibrium phase diagrams were determined for the systems 2,2-dimethylbutane-2,3-dimethylbutane and 2,2-dimethylbutane-cyclopentane. Each of these systems forms a series of continuous solid solutions containing a maximum in the diagram which is called a complex. For the system 2,2-dimethylbutane-cyclopentane the upper and lower transition temperatures were determined over the range of composition in which the transitions occurred as well as the heats of transition and heats of fusion. The lower transition is found only for the pure components and mixtures having compositions between 70 and 100 mole percent cyclopentane, while the heat of this transition per mole of mixture decreases from 1165 cal. at 100 mole percent cyclopentane to 0 cal. at approximately 68 mole percent cyclopentane. The upper transition was found only for the pure components and mixtures between 60 and 100 mole percent cyclopentane.

Vapor Pressures and Saturated Liquid and Vapor Densities of Cyclopentane, Methylcyclopentane, Ethylcyclopentane and Methylcyclohexane. WEBSTER B. KAY, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1273-7.

The boiling points and critical constants of cyclopentane, methylcyclopentane, ethylcyclopentane and methylcyclohexane were determined. The vapor pressures and saturated liquid and vapor densities of these compounds were determined from temperatures near their standard boiling points to their critical points. The data are represented by empirical equations: (a) the vapor pressure data by equations of the type $\log p = A + B/T$ supplemented

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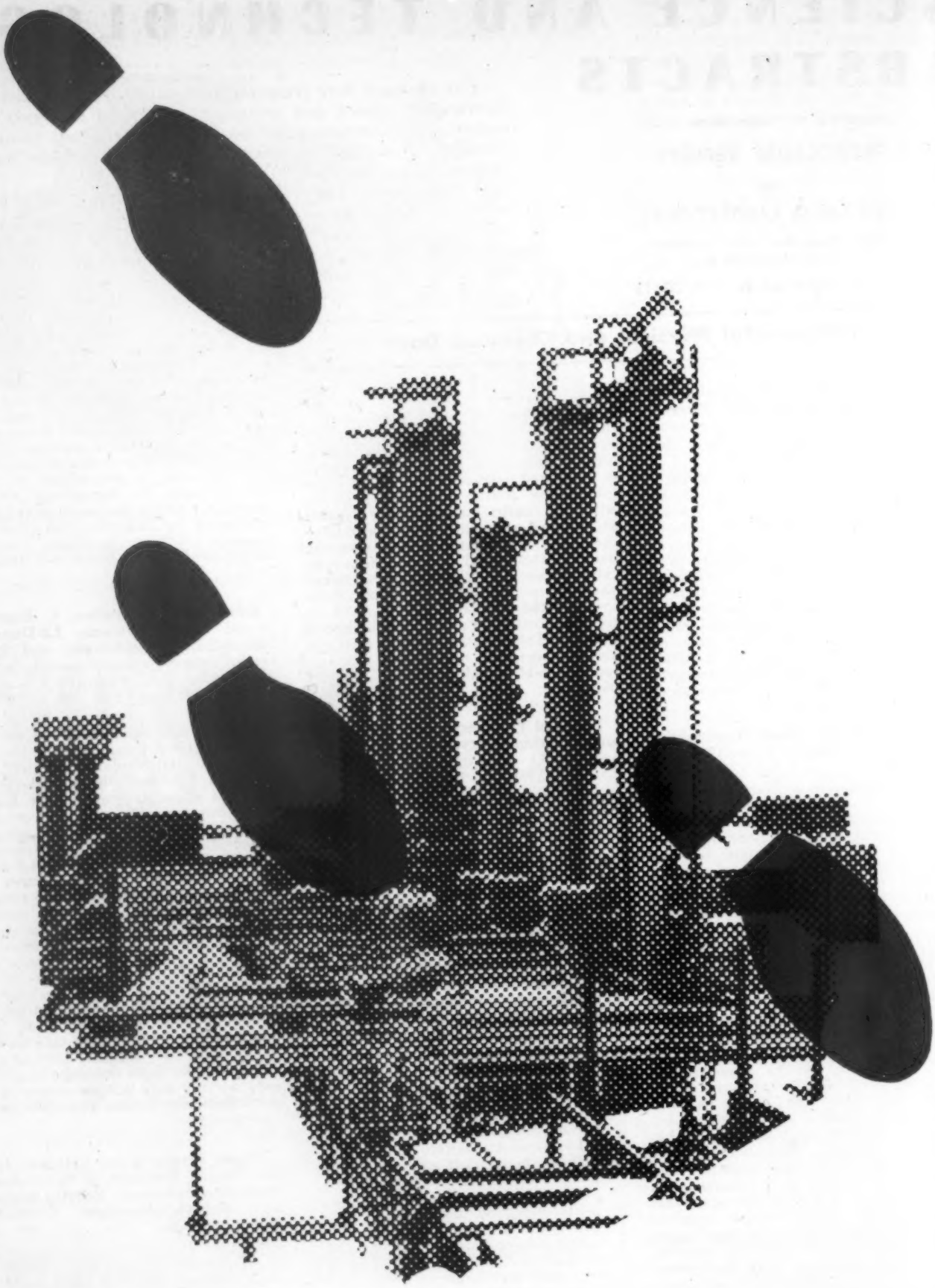
p-Fluorobenzotrichloride
p-Fluorobenzotrifluoride
p-Bromobenzotrifluoride
p-Iodobenzotrifluoride
Pentane-1, 3, 5-triol
sec-Amyl mercaptan
2-Methyl-3-chloro1, 4-naphthoquinone
2,2-Difluoropropane
Epinine
α-Benzylpyridine
γ-Benzylpyridine
Dialkyl or diaryl peroxides



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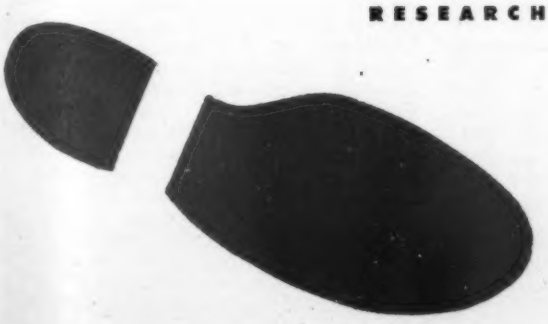

by deviation curves; (b) the density data by means of the equation of Fales and Shapiro, log log ρ_L/ρ_V = log k+m log-(1—T_R2) — n log T_R together with the equation for the sum of the liquid and vapor densities, $\rho L\ \rho V = \alpha + \beta t + \gamma t^3$. Values of the constants in the equations are given for each of the hydrocarbons.

Chemical Compositions and Reactions

Naphthenic acids: Boiling Points and Distribution in Gas Oil Distillates. K. F. COLES, *Jour. Inst. of Pet.* **33** (1947) pp. 325-9.

The fractionation of a Trinidad gas-oil at reduced pressure has enabled the distribution of naphthenic acids to be studied. It has been found that the naphthenic acids with acid values 350 to 250 boil 60° to 40° C. above the boiling points of the gasoil fractions in which they are found. The vapor-pressure/temperature relationship for some naphthenic acid fractions is presented.

The Addition of Hydrogen Chloride to Isobutylene. FRANK R. MAYO AND JOSEPH J. KATZ, *Jour. Am. Chem. Soc.*, **69** (1947) pp. 1339-48.

The addition of hydrogen chloride to isobutylene in heptane solution at 0° C. was studied using a dilatometric method. t-Butyl chloride was the only product found. The addition was greatly accelerated by traces of water, mercury and phosphorus pentoxide, all of which were difficult to exclude completely, and the experiments were therefore not entirely reproducible. The uncatalyzed reaction is apparently of the third order with respect to hydrogen chloride and of the first order with respect to isobutlyene, while the catalyzed reaction approximates the second order. An addition proceeding at 0° is greatly accelerated by cooling to —80° or below and then warming to 0°. The high order of the addition and the unusual effect of temperature are accounted for if hydrogen chloride-isobutylene complexes are involved in the reaction, but the possibility that the addition is a chain mechanism of the ionic type is not excluded.

The Addition of Hydrogen Bromide to Propylene. FRANK R. MAYO AND MICHAEL G. SAVOY, *Jour. Am. Chem. Soc.* **69** (1947) pp. 1348-51.

A preliminary study was made of the kinetics of the addition of hyrdogen bromide and propylene in n-pentane as solvent. The major obstacle was the difficulty in repressing the abnormal addition of hydrogen bromide, even in the presence of inhibitors. The rate of the uncatalyzed normal addition corresponds better to a fourth order reaction, third order with respect to hydrogen bromide, and first order with respect to propylene, than to any other integral order. The reaction is accelerated by hydroxylic compounds and then may be of a lower order. The results support the conclusions reached in the study of the hydrogen chloride-isobutylene reaction by the same authors.

Reaction of Propane with Carbon Monoxide in the Presence of Aluminum Chloride. HERMAN PINES AND V. N. IPATIEFF, *Jour. Am. Chem. Soc.* **69** (1947) pp. 1337-9.

Butanes and pentanes react with carbon monoxide in the presence of aluminum chloride to form a mixture of ketones and acids. The main product is methyl isopropyl ketone with smaller amounts of n-butyl i-butyl ketone and α-methylbutyric acid. To determine whether a tertiary carbon atom is required for the reaction to proceed, the reaction of carbon monoxide with propane was studied. The products obtained consisted of isobutyric acid, isobutyl isobutyrate and 2,5-dimethyl-4-henen-3-one, the yields of these compounds, respectively, being 5, 44 and 23 mole percent. The mechanism of the reaction is discussed.

Manufacture: Process and Plant

Calculation of Relative Volatility from Boiling Points. F. W. MELPOLDER AND C. E. HEADINGTON, *Ind. and Eng. Chem.* **39** (1947) pp. 763-66.

Interpretation of many fractional distillation problems is dependent on a knowledge of the relative volatility of the components involved. Where reliable vapor pressure curves are available the ideal relative volatility α of a binary mixture is calculated directly as the ratio of the vapor pressures of the components. A number of investigators have proposed methods for calculating the value of α from boiling points, but the authors have found that none have the desired degree of accuracy for application to precise distillation work. An improved method is described for calculating the ideal relative volatility of nonpolar binary mixtures from the boiling points of the components. Based on recent precise vapor pressure data, the value of α was correlated with temperature and pressure over a range of 300° C. and at a pressure down to 100 mm. of mercury. In order to facilitate the solution of distillation problems, a graphical solution of Fenske's total reflux equation for binary mixtures is given. A bibliography of 8 references is included.

Theory of the Performance of Packed Rectifying Columns. JOHN R. BOWMAN AND R. C. BRIANT, *Ind. Eng. Chem.* **39** (1947) pp. 745-51.

The purpose of the authors was to develop a theory of the performance of packed rectifying columns independent of the classical theory of bubble plate columns. The results are applicable to other countercurrent contact exchange processes as well. The fundamental differences between packed and bubble plate columns are discussed, and the differential material balance equations for the former are derived. These equations relate the flow, accumulation, and interphase transfer of each component within an element of column height. The interphase transfer rate of a component is assumed to be proportional to the amount of that component that would have to be transferred from one phase to the other to bring the phases into equilibrium. This assumption is equivalent to a special case of transfer unit theory in which the two transfer resistances are equal. With it, the material balance equations are integrated to yield equations of performance for special cases. Where direct comparison between these and classical formulas from bubble plate theory is possible, the two are analytically different but, for practical problems, give nearly identical numerical results. A bibliography of 16 references is included.

A Binary Mixture for Evaluating Low Pressure Distillation Columns. FREDERICK E. WILLIAMS, *Ind. and Eng. Chem.* **39** (1947) pp. 779-82.

Studies of the design and efficiency of fractionating columns for operation at low vacuum, such as 1 mm. pressure, have been seriously handicapped by lack of a suitable test solution for measuring rectification efficiency. Suitable specifications for such a test mixture are suggested. Requirements are met by mixtures of di-*n*-butyl phthalate and di-*n*-butyl azelate. Vapor-liquid equilibria are presented for this mixture at 1 mm. pressure. This binary system is shown to be satisfactory for determining the number of theoretical plates in low pressure distillation columns having as many as thirty plates. Two types of low pressure columns were compared by means of the new test mixture. One of these was an open tube column and the other a column fitted with a long spiral packing made by turning a square thread on an aluminum rod. The column with the spiral packing had nearly three times as many plates as the unpacked tube. A bibliography of 7 references is included.

Bubble Tray Hydraulics. JAMES A. DAVIES, *Ind. and Eng. Chem.* **39** (1947) pp. 774-78.

A well designed bubble tray should be balanced, flexible, and stable. Balance is the ability to maintain satisfactory efficiency under flowing conditions when operating with design loads of vapor and liquid. Flexibility is the ability to maintain satisfactory efficiency under conditions where either vapor or liquid rates are greater or less than those of the design. Stability is the ability to maintain satisfactory efficiency under changing flow or unsteady state conditions. One of the most important factors that make a balanced tray is liquid gradient. An equation is derived for calculating the liquid gradient in a tray from the common variables in tray design. A correlation of the liquid gradient factor contained in the equation is given. The correlation is based on test commercial trays using water and air. Comparison of the calculated liquid gradient with a measured gradient in a depropanizer gave a close check. A bibliography of 16 references is included.

Comparison of Rectification and Desorption in Packed Columns. DONALD W. WEED, P. W. SCHUTZ AND THOMAS B. DREW, *Ind. and Eng. Chem.* **39** (1947) pp. 766-74.

Rectification experiments with isopropanol-water mixtures and experiments on the desorption of oxygen and of carbon dioxide from water into air were performed in a 6-inch column packed with 47 inches of half-inch ceramic Raschig rings. Desorption results for liquid rates above 1000 lb./hr./sq.ft. checked closely with those of Sherwood and Holloway. At lower liquid rates, values of $(H.T.U.)_L$ for desorption of carbon dioxide were found to be a function of the liquid distributor. Most of the desorption data at low liquid rates gave values of $(H.T.U.)_L$ somewhat above an extrapolation of Sherwood and Holloway's work, but a few runs, made with 2 feet of packing and modified operation

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of the liquid distributor, gave results following their curve down to a liquid rate of 300 lb./sq.ft./hr. In the dilute isopropanol range, values of $(H.T.U.)_L$ were obtainable from the rectification data. These were converted to the system carbon dioxide-water (at 25 C.). The results were found to agree approximately with the values experimentally observed for that system. The experimentally observed values averaged about 0.6 foot over the range of liquid rates common to both the rectification and desorption sets of experiments—that is, 130 to 460 lb./sq.ft./hr. The apparatus and procedure are described and the data are presented in some detail in tabular and graphical form. A bibliography of 16 references is included.

Efficient Packing for Rectifying Columns. H. O. McMahon, *Ind. Eng. Chem.* **39** (1947) pp. 712-14.

A rectifying cloumn packing is described that is characterized by high throughput and excellent contacting ability. It is light weight and easy to make. One cubic foot weighs approximately 25 pounds and contains 450,000 pieces of packing. The packing is made from a quarter-inch square of 100-mesh wire cloth formed into a saddle-like shape. The material has been used extensively for the fractionation of liquid air in some oxygen plants built for armed forces.

Performance of McMahon Packing. W. L. Forsythe, *Jr.*, T. G. Stack, J. E. Wolf and A. L. Conn, *Ind. Eng. Chem.*, **39** (1947) pp. 714-18.

The authors tested McMahon packing, a new type of column packing made of wire gauze shaped in the form of Berl saddles, using the system benzene-ethylene dichloride to determine its fractionation performance. In a 6-inch column-filled with ¼-inch packing to heights of approximately 5 and 9 feet, H.E.T.P. values of 2 to 4 inches were obtained. These are compared with published results from Stedman packing in which H.E.T.P. values of 1.5 to 2 inches were obtained with a packed height of 3 feet. The pressure drop for McMahon packing is lower than that for Stedman packing, which makes it particularly useful for vacuum fractionation. The maximum capacity and liquid holdup are essentially the same for the two packings. McMahon packing has several advantages over Stedman packing since it does not require accurately machined columned walls, is not restricted to one column diameter, and is more rapidly installed and removed. The apparatus and test procedure are described in some detail and the data are presented in tabular and graphical form. A bibliography of 13 references is included.

Binary Mixtures of n-Butane, Isobutane, and 1-Butene with Furfural. T. S. Mertes and A. P. Colburn, *Ind. and Eng. Chem.* **39** (1947) pp. 787-96.

The design and selection of optimum operating conditions for extractive distillation columns depend on knowledge of how the relative volatilities of the components vary with composition and temperature. Preliminary to the work with representative multicomponent systems of hydrocarbons in furfural-water mixtures, a flow-type apparatus was developed and special experimental techniques were introduced to determine vapor-liquid equilibrium data for n-butane, isobutane, and l-butene in dry furfural at temperatures of 100°, 125°, 150°, and 200° F., at pressures up to 100 pounds per square inch gage, and at concentrations generally up to 25 mole % hydrocarbon. The data, corrected for nonideality of gases and volume of liquid, are interpreted as activity coefficients and are consistent. The activity coefficients are shown to be functions of concentration according to the Margules and the van Laar equations. Variations of activity coefficients with temperature were utilized to evaluate the heats of solution of the hydrocarbons in furfural. The data are presented in considerable detail in tabular and graphical form. A bibliography of 29 references is included.

Furfural Extractive Distillation. C. K. Buell and R. G. Boatright, *Ind. & Eng. Chem.* **39** (1947) pp. 609-705.

Extractive distillation using furfural for the separation and purification of C_4 hydrocarbons is used extensively in making butadiene in connection with the government synthetic rubber program. As a selective solvent, furfural alters the normal relative volatilities and makes possible the separation of several of the C_4 hydrocarbons which would be difficult, if not impossible, to make by simple fractional distillation. The authors present information relative to the development and commercial operation of the process. Solvent characteristics are considered, a commercial process flow arrangement is given, performance data are presented, and the effects of operating variables with respect to selection of process control methods and degree of separations obtained are discussed. Factors pertaining to selection of materials of construction and equipment items and their performance characteristics during more than three years of plant operations are reviewed.

Commercial Scale Manufacture of Allyl Chloride and Allyl Alcohol from Propylene. A. W. Fairbairn, H. A. Cheney and A. J. Cherniavsky, *Chem. Eng. Progress* **43** (1947) pp. 280-90.

The authors describe a process now in commercial operation for the production of allyl chloride by the high-temperature chlorination of propylene and one for the production of allyl alcohol by hyrdolysis of allyl chloride using auqeous sodium hydroxide. Both steps are continuous. Allyl chloride is made through the noncatalytic chlorination of propylene in the vapor phase at about 500° C. The principal reaction is the substitution of an atom of chlorine for an atom of hydrogen in the propylene molecule. The authors describe a full-scale plant and discuss the operating variables in the light of the more recent data available. Allyl alcohol is made commercially by the hydrolysis of allyl chloride with dilute caustic soda at a temperature of approximately 150° C. Diallyl ether is the major coproduct. The process variables are described and materials of construction and corrosion and other problems are considered. The properties of the allyl compounds and of other compounds of importance in connection with manufacturing allyl compounds are presented in tabular form. A bibliography of 8 references is included.

Organizing an Instrument Department. C. S. Comstock and H. U. Fisher, *Chem. Eng. Progress* **43** (1947) pp. 303-8.

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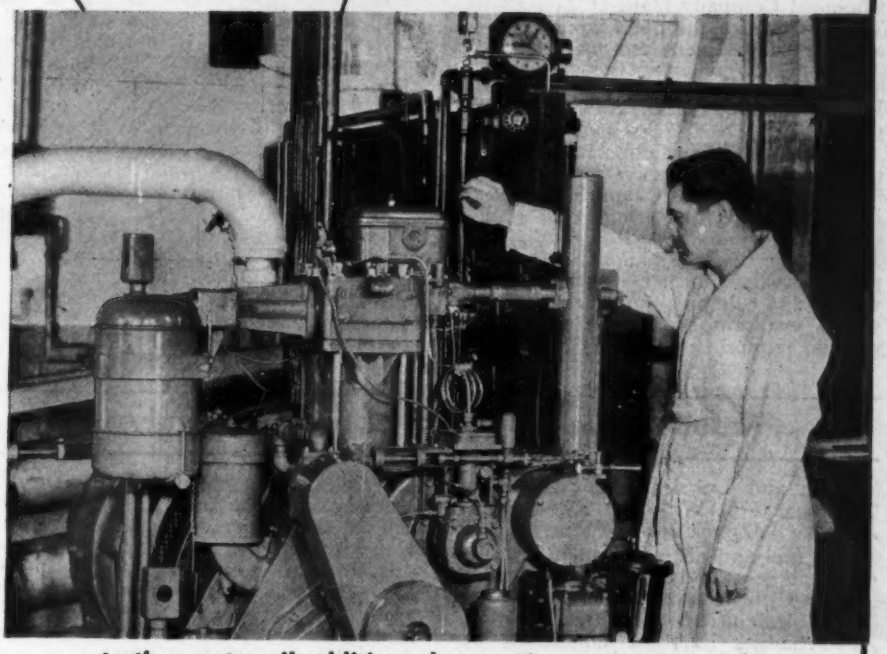

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maintenance and servicing of instruments have become operating functions of importance. In general these include maintenance, repair, and adjustment of the instruments so that they will fulfill their designed purpose and perform continuously and accurately. In addition, engineering functions of the instrument department include the development of new control methods and instruments. Preparation of daily tabulations of metered quantities is conveniently done by the instrument department, and the training of personnel is of the utmost importance. The authors describe the personnel and equipment that have been used to fill these needs in the Monsanto Chemical Company plant at Texas City, Texas. Costs of the operation of the instrument department are analyzed.

Equipment Cost Estimating Data—II. HARDING BLISS, *Chem. Eng.* 54 (1947) pp. 100-2.

The article is the concluding installment of a comprehensive article started in an earlier issue of Chemical Engineering. It extends and brings up to date the data originally compiled in 1941. Many basic types of equipment including pipe and valves, heat exchangers, filters, vessels and columns, thickeners and classifiers, evaporators, crystallizers, tanks, vessels, pumps, and motors were dealt with in the previous article. The present article covers gas pumps, crushing and grinding equipment, and dryers. Data are given in the form of curves.

Standardizing Cost Data on Process Equipment. ROGER WILLIAMS, JR., *Chem. Eng.* 54 (1947) pp. 102-3.

Published equipment costs information is seldom used for the final firm construction estimates that are required for the making of appropriations. For such estimates actual quotations should be used. Published cost ranges and curves are useful primarily to those who make order-of-magnitude economic analyses, and publishers should aim their data at these users. The major failing of the equipment cost information now available in the literature is that it is not on a consistent basis. It is not consistent as to price and wage levels which may vary widely from year to year, and as to inclusion of necessary accessories such as starters for motors, or heaters, cyclones for dryers, and the like. Frequently it does not include installation cost, and finally it is not consistent in including or excluding construction overhead. A basis of correlation is presented by the writer and is applied to mild-steel tanks and to heat exchangers, including condensers and evaporator calandrias. 4 references are included.

Products: Properties, Utilization and Analysis

Fuels and Lubricants for Aero Gas Turbines. C. G. WILLIAMS, *Jour. Inst. of Pet.* 33 (1947) pp. 267-324.

The fuel and oil requirements of aero gas turbines are largely determined at the present time by considerations of engine design and operating conditions. Any changes in these conditions can exert an important influence on the fuel and oil requirements so there is everything to be said in favor of close collaboration between the engine designer and the petroleum technologist. In regard to fuels, the general trend is towards a distillate fuel having a boiling range of 65-300° C. The relatively low viscosity and high volatility of such a fuel confers considerable advantages in relation to atomization, cold starting, blow-out, and carbon deposition. A fuel of this type can also be made available in large quantities. The main requirement of a lubricant at the present time is a low viscosity combined with the highest possible viscosity index. The development and application of additive-type lubricants for propeller-turbine engines is in hand, and their future will largely depend on certain details of engine design. The data considered are presented in tabular form in part and as 23 figures.

Rotary Concentric-Tube Distilling Column. CHARLES B. WILLINGHAM, VINCENT A. SEDLAK, FREDERICK D. ROSSINI AND JAMES W. WESTHAVER, *Ind. & Eng. Chem.* 39 (1947) pp. 706-12.

The authors describe the assembly and testing of a rotary concentric-tube distillation column, in which the rectifying section is an empty annular space 0.043 inch (1.09 mm.) in width formed by the inside surface of a stationary outer cylinder and the outside surface of a rotating, closed, inner cylinder. The latter cylinder is 2.93 inches (7.44 cm.) in outside diameter and 23.0 inches in length. Results are given for the number of theoretical plates at total reflux ratio and the pressure drop as determined in experiments at atmospheric pressure, at speeds of rotation from 0 to 4000 r.p.m., and at throughput values from 600 to 4700 ml. of liquid per hour. Typical results for the speed of rotation of 4000 r.p.m., calculated per meter length of rectifying section, are as follows: throughput, 3000 ml. per hour; pressure drop, 2.0 mm. of Hg; number of theoretical plates, 62; holdup, 17.5 ml. The calculated value of the efficiency factor, that is throughput divided by holdup per equivalent theoretical plate, for the foregoing conditions is about ten times the best values previously reported for other rectifying columns. Details of the column are represented in three figures and the data are given in tabular and graphical form. A bibliography of 20 references is included.

Automatic Microdetermination of Carbon and Hydrogen. RALPH O. CLARK AND GORDON H. STILLSON, *Anal. Chem.* 19 (1947) pp. 423-6.

In the microdetermination of carbon and hydrogen in organic compounds, a combustion unit that operates automatically shows important advantages over the conventional, manually operated apparatus. Using a semiautomatic combustion unit, combustion cycles for the analysis of a rather wide range of compound types were determined. The apparatus is described and the conclusions drawn from its operation are applied to the design of fully automatic units that have now been built and are in routine use. The combusition cycles employed are compared to those of other automatic units previously described.

Determination of Carbon and Hydrogen in Petroleum Distillates. A Lamp Technique. M. C. SIMMONS, *Anal. Chem.* 19 (1947) pp. 385-9.

A method for simultaneously determining the carbon and hydrogen content of organic substances, is based on their combustion in a special lamp suitable for aromatics as well as for other hydrocarbons. The lamp combustion procedure simplifies difficulties normally encountered in the conventional methods of ultimate analysis of volatile samples. Refinements improve the accuracy and permit use of relatively small samples. Routine determinations can be made with a maximum deviation for repeated analyses of about 0.01% from the mean when 0.5 to 1.0-gram samples are used. The apparatus and procedure are described in considerable detail.

Laboratory Low-Temperature Fractional Distillation. Optimum Charging Rates. C. E. STARR, JR., J. S. ANDERSON AND V. M. DAVIDSON, *Anal. Chem.* 19 (1947) pp. 409-13.

The analysis of mixtures of light hydrocarbon gases and gases such as hydrogen, nitrogen, oxygen, and carbon monoxide is ordinarily conducted first by segregation of fractions of low-temperature distillation range and second by analysis of the individual fractions. In such a procedure the lightest components are taken overhead from the distillation column during the charging of the samples. Published procedures for operation of low-temperature distillation equipment do not usually include sufficiently detailed instructions for charging samples of widely varying compositions in order to ensure obtaining overhead fractions of maximum purity with a minimum of charging time.

The authors studied the charging rates for samples such as are ordinarily encountered in petroleum refining plants. Overhead samples taken at different charging rates were analyzed by means of the mass spectrometer to determine whether they were contaminated with high boiling components. Results obtained indicate that charging rates much higher than those now customarily used can be used with equal accuracy. Also use of the higher charging rates effects considerable economy of time. Supplementary data obtained showed that for special applications distillation rates may be increased severalfold those now generally employed.

Positions Open

WANTED—MECHANICAL OR METALLURGICAL ENGINEER—familiar with the inspection of refinery fractionating equipment, furnaces, heat exchangers and pressure vessels and having experience to qualify for making recommendations for renewal or repairs to the equipment. Experience on catalytic cracking units preferred, but not essential. In replying, please send full details of experience and education. Snapshot (if available). Address: Box 10-R, c/o Petroleum Refiner, Houston, Texas.

ENGINEERS—Stanolind Oil and Gas Company, P. O. Box 591, Tulsa, Oklahoma, has opening for graduate chemical or mechanical engineer with two or more years experience in gasoline or recycling operations. Address: Box 206-R, c/o Petroleum Refiner, Houston, Texas.

Compact Is Extended

President Truman last month signed the joint congressional resolution extending for another four years or until September 1, 1951, the life of the Interstate Oil Compact Commission.

Some Duplex Tubing Applications

Heat Exchanger manufactured by Downingtown Iron Works, Downingtown, Pa. It is 10" O.D. by 16'0" tube length, using ⅝" O.D. Bridgeport Duplex Tubes with 70-30 Cupro Nickel outside and stainless steel inside. Tie rods made from Duronze III.

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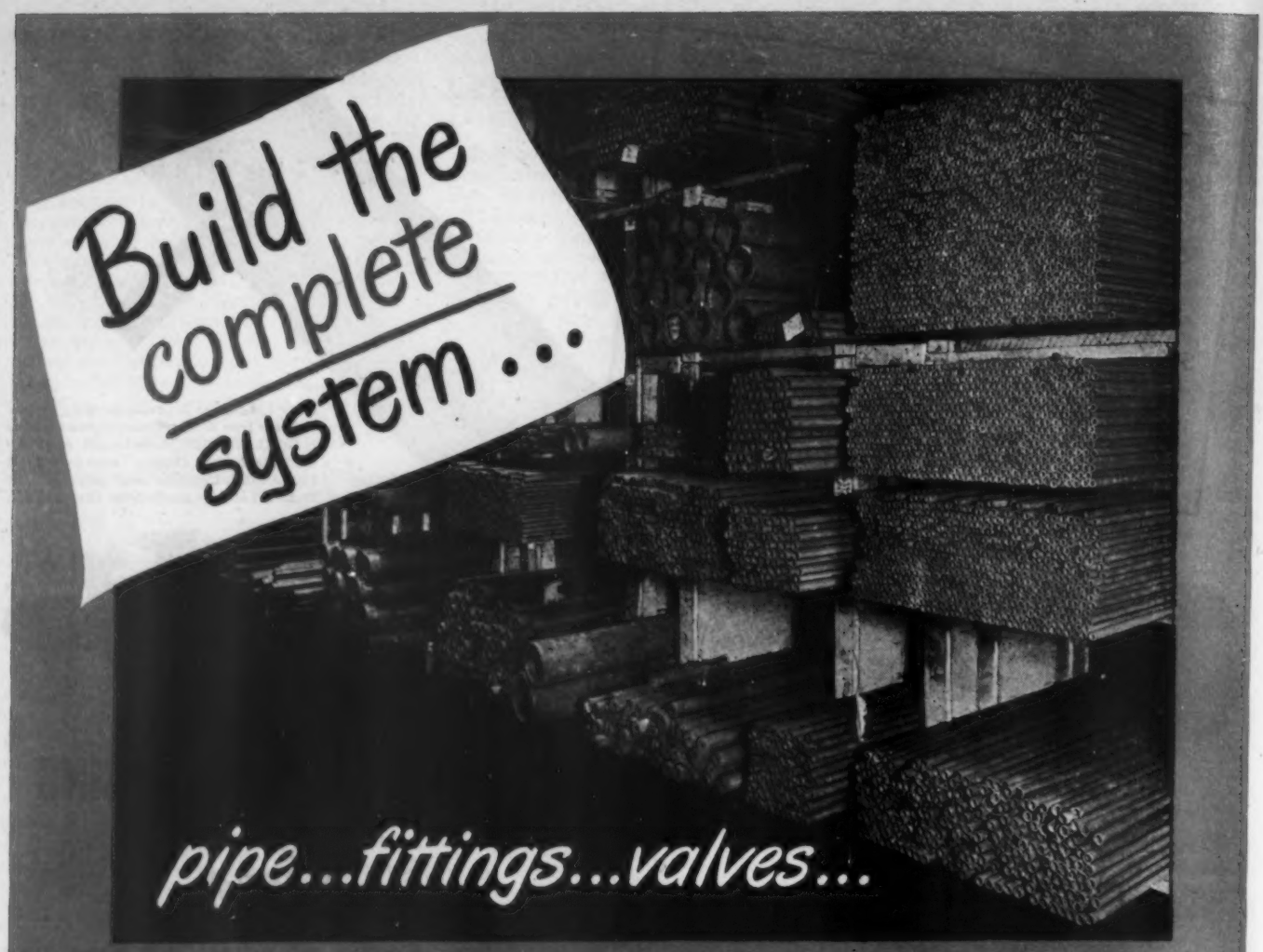

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Patents Pertaining to Petroleum Refining

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REFINING

U.S.P. 2,420,761. Process for Treating a Liquid with a Suspension of Solids by Passage Thereof Through a Separator, Renegerating the Separated Solids for Re-Use with Untreated Liquid. C. L. Thomas to Universal Oil Products Company.

A suspension of a subdivided solid in the liquid to be treated is introduced to the lower portion of a first contacting zone and passed upwardly through this zone. Solid particles are separated by gravity from the treated liquid in an upper region of the zone, and the treated liquid is removed from this zone. A stream of purifying liquid is simultaneously passed upwardly in a confined path within said zone. The separated particles are passed downwardly by gravity through the ascending stream of purifying liquid and are thereafter suspended in additional purifying liquid. The resultant suspension is passed upwardly through a second zone. The thus treated solid particles are separated by gravity from the additional liquid in an upper region of the second zone while a second stream of purifying liquid is simultaneously passed upwardly in a confined path within the second zone. The treated solid particles are passed downwardly by gravity through this ascending second stream of purifying liquid and are then returned to the first zone in suspension in a further quantity of the liquid to be treated. The process can, for example, be used in the refining of hydrocarbon oil in removing impurities adsorbed by solid particles.

U.S.P. 2,420,862. Stabilization of Vinyl Aromatic Compounds with Gaseous Diolefins or Acetylenes. T. S. Chambers to Standard Oil Development Company.

Aliphatic conjugated diolefins or acetylenes which boil below 10-30° C. are dissolved in vinyl aromatic compounds to be stabilized, such as styrene, in an amount up to the limit of solubility. Acetylene can, for example, be bubbled in the gaseous state through liquid styrene. Polymerization of the vinyl aromatic compounds is inhibited.

U.S.P. 2,420,906. Butadiene Extraction. J. W. Packie and R. A. Given to Standard Oil Development Company.

An olefin or diolefin, such as butadiene, is extracted from a mixture of unsaturated hydrocarbons by intimately contacting this mixture in a plurality of stages with a preferential solvent for an olefin or diolefin, such as an ammoniacal cuprous acetate solution. Each stage consists of a turbine-type agitator and a settling chamber. The solvent passes through the stages in progressively increasing olefin concentration while the hydrocarbon mixture passes through them in progressively decreasing olefin content. A solvent phase and a hydrocarbon phase is separated in each of the settling chambers. Each solvent phase is contacted with the hydrocarbon phase having a higher olefin concentration than the hydrocarbon phase from which it was separated, while the separated hydrocarbon phase in each case is contacted with a solvent phase having a lower olefin content than the one from which it had been separated. The solvent phase from the last settling chamber is heated and passed to a settling chamber to expel in the liquid phase substantially all hydrocarbons except the desired olefin. The expelled hydrocarbons are separated and recycled to the solvent phase passing to the agitator of the last stage. The olefin is finally recovered from said solvent phase, by vaporization at a sufficiently high temperature.

U.S.P. 2,420,915. Butadiene Extraction. J. K. Small and R. A. Given to Standard Oil Development Company.

Butadiene is separated from compositions containing butadiene and acetylenes by introducing into an intermediate part of a desorber a solution relatively rich in butadiene of a copper salt capable of forming addition compounds with butadiene and acetylenes. Part of the butadiene content of this rich solution is desorbed. The solution is withdrawn from a lower point of the desorber to a heating zone to desorb a further quantity of butadiene. The heated solution is reintroduced at a still lower point in the desorber to permit the butadiene vapor released from this heated solution to flow countercurrent to the first-named rich solution, thus leaving some acetylenes in a lean solution. The lean solution is withdrawn from the lower part of the desorber to a heating zone where the acetylenes are polymerized and removed. A part of the thus reconditioned solution is recycled to a point above said intermediate part of the desorber.

U.S.P. 2,421,229. Process for the Separation of Isobutene from a Mixture of C_4 Hydrocarbons. G. B. Zimmerman to Universal Oil Products Company.

A mixture of C_4 hydrocarbons containing isobutene and butene-1 is contacted with an olefin isomerizing catalyst, such as a phosphoric acid or a silica-alumina catalyst, under conditions regulated to selectively isomerize the butene-1 to butene-2 without substanially isomerizing the isobutene. The isobutene is then fractionated from the resulting isobutene-butene-2 mixture.

CATALYST PREPARATION, ACTIVATION, AND REGENERATION

U.S.P. 2,420,542. Carrying Out Chemical Reactions in the Presence of Finely-Divided Solids. C. E. Jahnig to Standard Oil Development Company.

In the regeneration of finely-divided solid material by hot oxidizing gases for the removal of combustible deposits, the regeneration gases removed from the regenerating zone and containing entrained solids are passed while substantially at regeneration temperature upwardly through a layer of finely-divided solid material maintained in a turbulent condition. A cooling fluid is passed in indirect heat exchange with the layer of solid material to maintain its temperature materially below the temperature of the regenerating zone, so that the temperature of the regeneration gas is correspondingly reduced. Entrained solid material is thereafter separated from the regenerating gas having passed through said layer.

U.S.P. 2,420,563. Catalyst and Process for Dehydrogenation of Hydrocarbons. P. W. Reynolds, A. W. C. Taylor, and J. G. M. Bremner to Imperial Chemical Industries, Ltd.

In the dehydrogenation of hydrocarbons a catalyst is used which is obtained by first adding to an aqueous aluminum salt solution, free of chromium, ammonia or a carbonate of ammonia in an amount sufficient to precipitate substantially all of the aluminum present. The resulting hydrous aluminum oxide precipitate is then impregnated with ammonium chromate or ammonium dichromate. To the resulting preparation an amount of about 0.05-5 percent by weight of an alkali metal compound or a zinc compound of a chromate or dichromate or a chromite is added, and the resulting product is cautiously thermally decomposed. The catalyst thus obtained when used in the dehydrogenation of hydrocarbons can be more completely regenerated for any given temperature of dehydrogenation and regeneration than other known catalysts. Moreover, it does not show any appreciable fall in mean activity per cycle when employed at temperatures of the order of 500-600° C.

U.S.P. 2,420,632. Cracking of Hydrocarbon Oils. C. W. Tyson to Standard Oil Development Company.

Contaminated solid contact material used in the conversion of hydrocarbon oils is passed successively through a plurality of adjacent combustion zones, these zones constituting a single continuous passage of progressively increasing volume. A portion of the contaminants is burnt during passage through each of these zones. The contact material is cooled during passage from one of these zones to the next succeeding zone. An oxidizing gas is separately introduced into each of the zones.

U.S.P. 2,421,212. Operation of Fluidized Systems. W. V. Medlin to Shell Development Company.

Vapors of hydrocarbons are cracked or otherwise converted by recycling a solid catalyst in the form of particles ranging from about 0 microns in diam-

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eter to about 100 mesh through a reaction or treating zone and maintaining this catalyst in a fluidized condition in this zone by means of a stream of the vaporized hydrocarbons to be treated. Suspended catalyst particles are continuously separated from the treated vapor in a fractional manner so that portions of catalyst particles of different average-particle size are separated from one another. Separated particles of a diameter of from 20 microns up are recycled to the main portion of the catalyst and particles of smaller diameter are withdrawn from the system in such an amount as to maintain the concentration of particles between 0 and 20 microns in the system below about 5 percent.

U.S.P. 2,421,664. Contacting Fluids with Solid Particles. C. W. Tyson to Standard Oil Development Company.

In the catalytic conversion of hydrocarbons a mixture of hydrocarbon vapors and finely divided catalyst particles is passed through a reaction zone and the fouled catalyst particles are separated from the reaction products in at least one stage and are then collected in a hopper. The main new feature of the process is that the catalyst particles are returned to the hopper below the level of catalyst particles contained therein.

CRACKING AND REFORMING

U.S.P. 2,420,534. Catalytic Cracking of Hydrocarbon Oils. E. J. Gohr, D. L. Campbell, J. M. Graham, and W. I. Thompson to Standard Oil Development Company.

Hydrocarbon vapors are mixed with a finely divided cracking catalyst to form a suspension. This suspension is passed through a cracking zone maintained at a temperature of 800-1000° F. and is kept within this zone for a period sufficient to convert at least 30 percent of the vapors into motor fuel constituents. The cracked vapors are separated from the catalyst, and a motor fuel distillate is fractionally separated from the vapors. The separated catalyst is suspended in a stream of inert gas to remove volatile hydrocarbons retained. The inert gas is then removed from the catalyst which is thereafter suspended in an oxidizing gas. The suspension thus formed is successively passed through a plurality of regenerating zones maintained at a temperature sufficient to burn carbonaceous deposits. Fresh oil to be cracked is passed in heat exchange relation with said suspension under regeneration between the successive regenerating zones. The regenerating stream is thus sufficiently cooled to keep its temperature below 1200° F. The regenerated catalyst is separated from the regenerating gas and returned to the cracking zone.

U.S.P. 2,420,900. Treating Hydrocarbon Fluids. J. E. Moise to Standard Oil Development Company.

A stream of fresh hydrocarbon oil to be cracked is passed through a cracking zone containing an active cracking catalyst maintained at cracking temperature at a rate which will substantially crack the oil into gasoline constituents. The catalyst is continuously circulated first through this cracking zone, thereafter through a regenerating zone where it is regenerated by burning off combustible deposits, and then again through the cracking zone. The cracked vapor products are fractionated in the cracking zone to separate an olefinic gasoline fraction. A portion of this fraction is mixed with hot regenerated catalyst while the latter is substantially at regenerating temperature, and the mixture thus obtained is combined with the stream of fresh oil to be introduced into the cracking zone. A gasoline of lower olefin content is obtained.

U.S.P. 2,420,904. Conversion of Hydrocarbons. H. D. Noll to Socony-Vacuum Oil Company, Inc.

A high boiling hydrocarbon feed stock is separated into a vapor fraction heated to about 840° F. and a liquid fraction. The vapors are cracked in the presence of a solid particle-form contact mass. The entire effluent of this primary cracking is mixed with the heated liquid fraction first obtained. This mixture is subjected to a second vapor separation step to form a second vapor fraction having a temperature of about 840° F. This second vapor fraction is again catalytically cracked while the second liquid fraction is discarded from the system. Hydrocarbons of gasoline boiling range are obtained.

U.S.P. 2,421,614. Treating Hydrocarbon Fluids. H. J. Hall to Standard Oil Development Company.

A relatively high boiling hydrocarbon fraction is catalytically cracked at a temperature of 900-1000° F. to produce lower boiling constituents containing aromatics and paraffins. An aviation

gasoline fraction and a heavy naphtha fraction boiling higher than the end point of the gasoline fraction are separated from the cracked products. The heavy naphtha fraction having a boiling range of 320-450° F. contains aromatics boiling too high for inclusion in aviation gasoline. This heavy fraction is thermally cracked at a temperature of at least 1200° F. for not more than a few seconds. High boiling aromatics are thereby converted to lower boiling aromatics. A fraction within the aviation gasoline boiling range and containing substantially only aromatics is separated from the products of the second cracking step. This separated fraction can be used as an aromatic blending stock. A synthetic silica alumina gel catalyst can be employed in the catalytic cracking operation.

U.S.P. 2,421,615. Treating Hydrocarbon Fluids. R. M. Shepardson to Standard Oil Development Company.

A relatively high boiling hydrocarbon fraction in the gas oil boiling range is maintained in a catalytic cracking zone at a temperature of 800-1500° F. A gasoline fraction boiling between 225° and 350° F. is separated from the products of the cracking operation and passed to a thermal cracking zone maintained at a temperature of 1400° F. where it is subjected to cracking for about 1 second. A gasoline fraction boiling in the aviation gasoline boiling range is separated by fractionation from the products of the thermal cracking.

U.S.P. 2,421,616. Catalytic Treatment of Hydrocarbon Oils. C. E. Hemminger and E. J. Gohr to Standard Oil Development Company.

Hydrocarbon oil is cracked in the presence of a catalyst which continuously circulates through a cracking zone. Oils of different coking characteristics are passed through this zone at different times. The amount of catalyst in this zone is controlled to convert a uniform and predetermined amount of the oil into coke irrespective of the coke-forming characteristics of the oil under treatment. The amount of coke thus produced shall be sufficient when burnt in a catalyst regeneration zone to supply the major portion of the heat requirements for the cracking process.

U.S.P. 2,421,651. Conversion of Hydrocarbon Oils. E. D. Reeves to Standard Oil Development Company.

Heavy residual oils to be converted into lower boiling hydrocarbons are mixed with a solid adsorbent contact material. The mixture is passed through a conversion zone at a temperature and for a period of time sufficient to convert a substantial portion of the oil into lower boiling hydrocarbons. The conversion products are fractionated to segregate a light fraction boiling above the motor fuel boiling range, an intermediate fraction, and a heavy fraction. At least a portion of the light fraction is combined with the heavy fraction and returned to the conversion zone. The intermediate fraction is subjected to separate cracking in the presence of a finely divided catalyst.

ISOMERIZATION

U.S.P. 2,421,674. Preparation of Isoparaffins and Reactivation of the Catalyst Used Therein. G. W. Ayers, E. E. Harton, and L. M. Henderson to The Pure Oil Company.

Straight chain hydrocarbons within the gasoline boiling range and containing 4-10 C atoms per molecule are passed through a Friedel-Crafts type catalyst under conditions suitable for converting straight chain to branched chain hydrocarbons, until the catalyst has formed a hydrocarbon complex and the yield of branched chain hydrocarbons has dropped to a predetermined amount. The stream of straight chain hydrocarbons is then discontinued and replaced by a stream containing substantially only isobutane and/or isopentanes. This stream is passed through the catalyst under conditions suitable for reactions between these branched chain paraffins and the hydrocarbons in the catalyst complex. The passage of this stream is continued until the catalyst is at least partially reactivated, whereupon the feed of straight chain hydrocarbons is resumed.

ALKYLATION

U.S.P. 2,421,331. Production of Alkylaromatics. E. A. Johnson to Standard Oil Company of Indiana.

Mononuclear alkylaromatic hydrocarbons boiling within the aviation gasoline range, and preferably monalkyl benzenes, are produced by alkylating mononuclear aromatics with olefins in the presence of a catalyst. The effluent of the alkylation is introduced into a gas separation zone into which is also introduced a second relatively cool polyalkylated aromatic liquid fraction obtained in a later phase of the process. Gases are withdrawn overhead for this zone. A combined liquid stream of polyalkylated aromatics is withdrawn from the separating zone. Benzene and polyalkyl aromatics are introduced into a second contacting zone where they are contacted with another quantity of the alkylation catalyst at a temperature substantially above that in the alkylation zone, whereby conversion to monoalkyl aromatic hydrocarbons is effected. A benzene fraction, a monoalkylbenzene fraction and a heavy polyalkyl aromatic fraction are recovered from the conversion products of the second contact zone. The heavy alkylaromatic fraction is supplied to the separation zone. At least a portion of the intermediate alkylaromatic fraction is subjected to the first-mentioned alkylation. The benzene fraction is recycled to the second contacting step.

U.S.P. 2,420,369. Acid Alkylation of Isoparaffins. A. R. Goldsby to The Texas Company.

In order to alkylate isoparaffins with olefiins, the olefin, such as propylene, is reacted with H_2SO_4, preferably of less than 90 percent concentration, to form an alkyl sulfuric acid compound. The separated acid compound is reacted in the presence of strong H_2SO_4, preferably of more than 90 percent concentration, with an isoparaffin, such as isobutane. A branch chain saturated hydrocarbon boiling within the gasoline range is obtained.

POLYMERIZATION AND CONVERSION

U.S.P. 2,420,327. Polymerization of Hydrocarbons. W. B. Shanley to Universal Oil Products Company.

An olefinic gas stream is passed through a bed of relatively active polymerizing catalyst, such as fresh solid phosphoric acid catalyst, while a second stream of olefinic gas is passed through a bed of less active polymerizing catalyst, such as partially spent solid phosphoric acid catalyst. A portion of the charging stock is heated to a temperature suitable for effecting polymerization in the second mentioned bed. Separate portions of the heated gas are supplied to the beds. An unheated portion of the charging stock is commingled with the heated gas for the first-mentioned catalyst in sufficient amounts to maintain in this first zone an average polymerizing temperature substantially uniform with the average polymerizing temperature prevailing in the second zone.

U.S.P. 2,420,386. Reduction of Corrosive Action of Friedel-Crafts Type Catalysts. W. R. Smith and W. F. Glassmire to The Texas Company.

The patent relates to a process for the catalytic conversion, e.g. isomerization, of hydrocarbons in liquid phase at elevated temperatures below 250° F. in the presence of a liquid aluminum halide-hydrocarbon complex catalyst and a hydrogen halide promoter in a reaction zone bounded by a metal wall which is submerged in the catalyst liquid and normally subject to corrosion thereby. To impede such corrosion the Al halide-hydrocarbon complex liquid is preheated in the absence of free hydrocarbons in a separate treating zone at a temperature of about 150-250° F. for a period of time of about 30-60 hours. The preheated complex liquid is then passed to the reaction zone to be used as the conversion catalyst. The pretreated complex liquid is substantially non-corrosive to boiler steel immersed therein at about 210° F.

U.S.P. 2,420,558. Catalytic Conversion of Hydrocarbons. J. C. Munday to Standard Oil Development Company.

In the catalytic conversion of a charging stock by means of a regenerable finely-divided catalyst, the finely-divided catalyst is maintained in a fluidized state first in the gaseous charging stock and then in the regeneration gas. The catalyst is recycled in the process with a minimum expenditure of energy and a minimum resistance to flow by mounting one of the two reaction zones (the conversion zone or the regeneration zone, respectively) at a higher level than the other zone. The material in the other reaction zone is maintained as an aerated column in communication with the first reaction zone and the separation zone. A first reactant stream is introduced at a high point in the higher level zone and the catalyst is introduced into the top of this zone. Both the reactant stream and the catalyst are passed concurrently downward through this zone and withdrawn from the lower part of the zone. Catalyst is separated from the reactant stream and is downwardly withdrawn into the top of the lower zone. A second reactant stream is introduced into the upper portion of this lower zone and passed downwardly concurrently with the catalyst in this zone and withdrawn together with reactant from the lower part of this zone. Catalyst is separated from the second reactant stream and conveyed by a gaseous stream back to the higher level reaction zone, while producing a density of the fluidized solid, at least within the

first reaction zone, within the range of 25-75 percent of the density of the freely settled solid.

U.S.P. 2,420,477. Production of Butadiene by Method of Dehydration. W. J. Hale and H. Miller to National Agrol Company, Inc.

Vinyl ethyl ether is reacted with ethylene to form butadiene at a temperature of 125-250° C. in the presence of a catalyst comprising a core of Be, Mg, Zn, Cd, or Al, or alloys thereof, and a coat of a partially reduced oxide of a metal from family A of group V or VI of the periodic system.

U.S.P. 2,420,688. Production of Styrenes and Other Products. M. G. Sturrock and T. Lawe to Dominion Tar & Chemical Company, Ltd.

Mononuclear aromatic compounds such as p-methyl styrene are produced by heating an asymmetric diaryl substituted paraffin or a nuclear substituted derivative with at least 2 C atoms in the paraffin chain to a temperature of at least 350° C. and passing the heated substance through a finely divided catalyst which promotes simple molecular decomposition at such a rate as to provide a contact time with the catalyst of between about 0.004 and 0.4 seconds. Hydrated aluminum silicate can be employed as the catalyst. Alpha, alpha ditolyl ethane mixed with water can, for example, be used as the charge stock.

U.S.P. 2,420,689. Process for Producing Nuclear Substituted Dimethyl Styrenes from Asymmetric Dixylyl Ethanes. M. G. Sturrock and T. Lawe to Dominion Tar & Chemical Company, Ltd.

This process is similar to that of U.S.P. 2,420,688, an asymmetric dixylyl ethane, such as di(m-xylyl) ethane, is heated to a temperature of at least 350° C. in the presence of a siliceous catalyst which promotes simple molecular decomposition. Mononuclear aromatic compounds including dimethyl styrene are obtained.

U.S.P. 2,420,750. Process for Polymerizing Conjugated Butadienes in the Presence of a Hexa-Aryl Ethane, and Products Thereof. D. Josefowitz to Publicker Industries, Inc,

The patent describes the production of a synthetic polymer of a conjugated butadiene hydrocarbon having combined therewith 0.5-2.0 parts of a hexa-aryl ethane (e.g. hexa-phenyl ethane) per 100 parts of butadiene hydrocarbon. The conjugated butadiene hydrocarbon is is polymerized at a temperature of 100-120° C. for 24-100 hours.

U.S.P. 2,421,326. Refortification of Aluminum Halide-Hydrocarbon Complex Catalysts. J. L. Groebe, W. B. Reeves, and D. C. Campbell to Phillips Petroleum Company.

A stream of isoparaffin feed to be converted is passed in a net effective direction of flow extending upwardly at an acute angle through an upper portion of a chamber containing granular aluminum halide. The rate of flow of this stream is controlled so that the amount of aluminum halide required for catalyst fortification becomes suspended in the isoparaffin stream during its passage through the upper portion of the chamber. After removal of aluminum halide from this portion of the chamber the incoming stream of isoparaffin is passed

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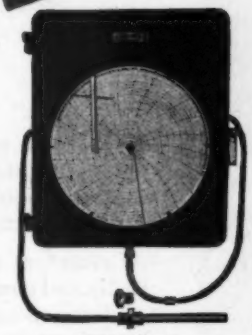

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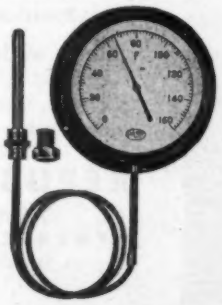

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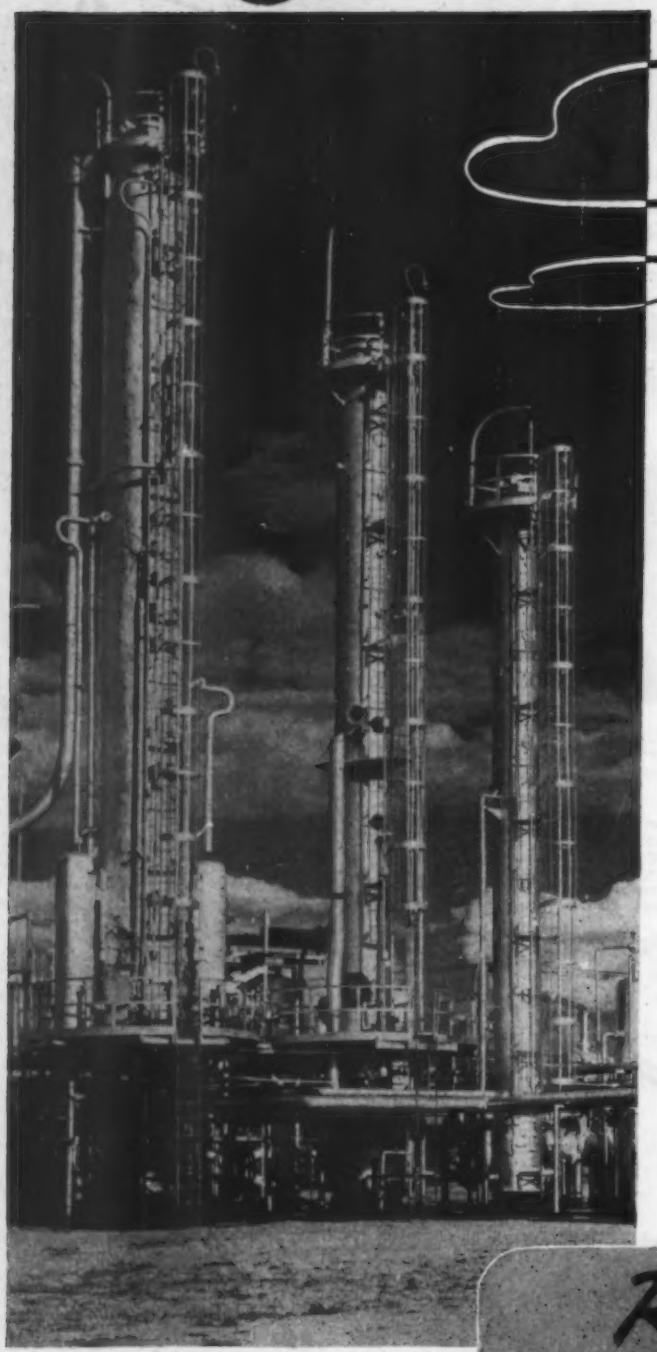

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in a net effective direction of flow extending upwardly at an acute angle through a lower portion of the chamber containing aluminum halide at a rate of flow corresponding to that used before in the upper portion of the chamber. Isoparaffin containing suspended aluminum halide is withdrawn from the chamber and introduced into a reaction zone where it is contacted with the aluminum halide-hydrocarbon complex catalyst requiring fortification. Isobutane can, for example, be converted by this process, using a temperature of not more than 100° F.

U.S.P. 2,421,422. Interpolymerization of Isobutene and Isopentenes in the Presence of Sulfuric Acid. G. C. Johnson to Socony-Vacuum Oil Company, Inc.

Isopentenes and isobutene are absorbed in H_2SO_4 of 58-66 percent concentration at tempertatures below 45° C. The resulting mixture is heated to about 45° C. and its temperature is then gradually increased to about 80° C. In a period of time not less than 30 minutes. High yields of nonenes are obtained.

U.S.P. 2,421,524. Purification of Metal Halide Catalyst in Catalytic Hydrocarbon Conversions. W. E. Ross and G. J. Carlson to Shell Development Company.

A mixture of a major portion of saturated aliphatic hydrocarbons and a minor portion of aromatic hydrocarbons is contacted at conversion conditions with a fluid Friedel-Crafts type metal halide catalyst. Converted hydrocarbons and a portion of the catalyst containing absorbed aromatic hydrocarbons are passed from the conversion zone into a first distillation zone where a vapor fraction comprising aliphatic hydrocarbons is separated from a liquid fraction comprising fluid catalyst with absorbed aromatic hydrocarbons. This liquid fraction is passed to a second distillation zone where the absorbed aromatic hydrocarbons are completely separated from the catalyst as a vapor fraction and removed without decomposition of the catalyst. The catalyst is then recycled to the conversion zone. The passage of catalyst from the conversion zone to the distillation zone is effected at a rate sufficiently high to avoid the accumulation of absorbed aromatic hydrocarbon in the catalyst in the conversoin zone. Isomerization of isomerizable saturated aliphatic hydrocarbons, can, for example, be carried out by means of this process. The presence of aromatic hydrocarbons in the treated mixture does not interfere with the desired conversion of the aliphatic hydrocarbons.

U.S.P. 2,421,619. Production of Motor or Aviation Fuels. D. A. Howes to Anglo-Iranian Oil Company, Ltd.

C_4 hydrocarbons containing olefins, such as are derived from the distillation and stabilization of crude oil and from cracking operations, are subject to cold acid polymerization in a preliminary liquid phase absorption stage carried out at about 0-40° C. The hydrocarbons and H_2SO_4 of 55-60 percent strength are cooled in this stage before admixture and are maintained cool during reaction. The absorption continues until the sp.g. of the acid liquor has been reduced to a degree substantially short of that at which the total water content of the acid has been used. Isobutylene is absorbed in the acid with the formation of tertiary butyl alcohol.

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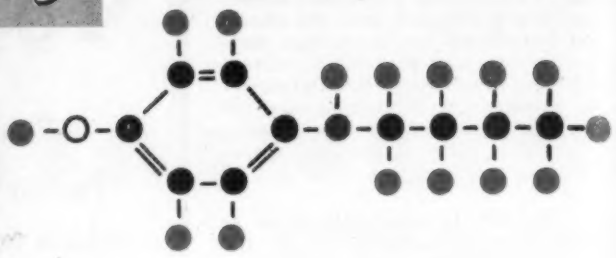

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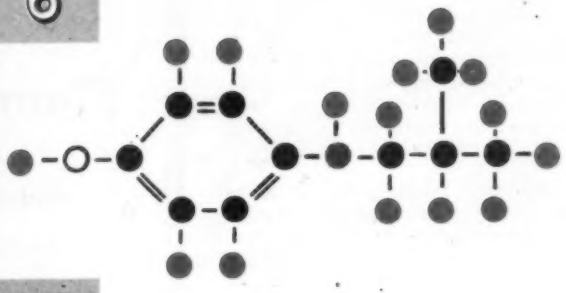

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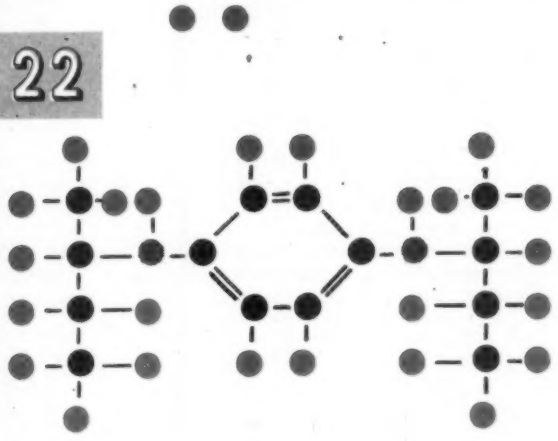

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HYDROGENATION DEHYDROGENATION AROMATIZATION

U.S.P. 2,420,749. Treatment of Monocyclic Olefinic Hydrocarbons. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

A monocyclic diolefinic hydrocarbon containing a ring of 6 C atoms, e.g. a monocyclic terpenic hydrocarbon such as limonene, is reacted in the presence of a dilute aqueous solution containing about 0.1-5 percent by weight of an acid acting catalyst, such as $MgCl_2$, at a temperature of 100-400° C. Aromatic hydrocarbons, such as p-cymene, are obtained.

U.S.P. 2,420,883. Process for the Production of Toluene. A. J. Johnson and J. E. Marsland to Shell Development Company.

A fraction comprising alkyl pentamethylene hydrocarbons is separated from naphthenic petroleum distillates and is then isomerized to methyl cyclohexane. The isomerized feed is fractionated into a lower boiling fraction boiling below 218-235° F. and a higher boiling fraction boiling above this temperature range. The lower boiling fraction is catalytically dehydrogenated to produce an aromatic fraction. Fixed gases including hydrogen are separated from the aromatic fraction. At least a portion of the fixed gases is scrubbed with a portion of said higher boiling fraction and this part of the higher boiling fraction is then fractionated to produce said lower and higher boiling fractions. Toluene is recovered from the product of the dehydrogenation of methyl cyclohexane.

U.S.P. 2,421,506. Manufacture of Diolefins. J. P. Jones to Phillips Petroleum Company.

A low boiling diolefin, such as butadiene, isoprene, or piperylene, is obtained by catalytically dehydrogenating a low-boiling hydrocarbon fraction containing predominantly paraffin hydrocarbons of 4 or 5 C atoms. A diolefin fraction and a hydrocarbon fraction comprising olefins but substantially free of diolefins are separated from the effluent. A major portion of this olefin fraction is passed again to the dehydrogenation step while a minor portion of the same fraction is subjected to non-destructive hydrogenation to form a paraffinic fraction. Paraffins having a C skeleton different form the first hydrocarbons are separated from this paraffinic fraction while the remaining part of this fraction is also passed to the dehydrogenation step.

U.S.P. 2,421,677. Catalytic Conversion of Hydrocarbons. A. Belchetz to The M. W. Kellogg Company.

Aliphatic hydrocarbons are converted to aromatic hydrocarbons by suspending a powdered hehydrogenating and cyclicizing catalyst in vapors of the aliphatic hydrocarbons. The catalyst most of which passes a 200-mesh screen, has previously been heated to a temperature approximating the conversion temperature. The suspension is passed upwardly through a conversion zone at a velocity of about 1-3 feet per second under superatmospheric pressure and at elevated temperatures suitable to largely dehydrogenate and cyclicize the aliphatic hydrocarbons to aromatic hydrocarbons. The proportions of heated catalyst and hydrocarbons introduced to the conversion zone are maintained within limits in terms of catalyst-to-hydrocarbons, by weight, of about 2-20 to 1 so as to supply the endothermic heat of reaction without supplying extraneous heat to the reaction mixture. A low octane naphtha can, for example, be converted to a highly aromatic high octane motor fuel. An oxide of a metal of the left-hand column of group VI of the periodic table can be employed as the catalyst.

DESULFURIZATION

U.S.P. 2,420,544. Process for the Removal of Mercaptans from Petroleum Naphtha. M. C. K. Jones to Standard Oil Development Company.

Petroleum naphthas containing mercaptans are mixed with a solution of caustic. The mixture thus formed is subjected to a mechanical shearing pressure of 2000-5000 psi. obtained by forcing this mixture through a small orifice, e.g. through the extremely small opening of a valve. The caustic is then immediately separated from the naphtha. The caustic, e.g. a sodium hydroxide solution, is by this treatment most intimately mixed with the naphtha to be sweetened and the mercaptans are removed to a considerably higher degree from the naphtha than in the customary batch agitation.

U.S.P. 2,421,320. Method of Desulphurizing Hydrocarbon Oils. J. C. Ernest to Mid-West Refineries, Inc.

Vapors of motor fuel hydrocarbons are passed through a bed of solid adsorbent catalytic material consisting essentially of clay converting sulfur compounds present in the hydrocarbons into more easily removable sulfur compounds. In order to extend the catalytic activity of the catalyst bed a hydrocarbon boiling within the gasoil range is simultaneously heated to a temperature substantially equal to that of the motor fuel vapors and the heated gasoil is introduced into the catalyst bed as a menstruum to remove converted sulfur compounds tending to inactivate the catalyst. The motor fuel vapors and the gasoil are removed from the catalytic zone, liquid hydrocarbons are separated from hydrocarbon vapors and the latter are condensed to obtain a motor fuel of low sulfur content. A temperature of about 650° F., and super-atmospheric pressure of about 50 p.s.i. can be employed.

U.S.P. 2,421,545. Mercaptan Oxidation Process. W. W. Crouch to Phillips Petroleum Company.

Alkyl mercaptan of high molecular weight (in excess of about 174), is treated with an aqueous $CuCl_2$ solution. The resulting product is treated in the presence of HCl with H_2O_2 in an amount sufficient to effect complete oxidation of the mercaptans to disulfides. This additional second treatment converts also those mercaptans to disulfides which withstand the usual treatment with $CuCl_2$. The process is particularly useful in the sweetening of petroleum distillates.

HEAVY OILS AND WAXES

U.S.P. 2,420,418. Apparatus for Dewaxing Oils. E. M. Dons and O. G. Mauro to Mid-Continent Petroleum Corporation.

The apparatus for filtering wax from oils comprises a cooling system provided with an elongated blending passageway having an inlet near one end for a stream of wax bearing oil and an outlet near the opposite end. A series of intermediate inlets for cooled dewaxing solvent to be mixed with and dissolved in the wax bearing oil is also provided in said passageway. Cooling coils communicating with said outlet of the blending chamber are provided to receive the outgoing mixture of solvent and waxy oil. These coils have successive inlets for incoming streams of cooled dewaxing solvent and separate regulating means for the successive streams. The regulating means are set to progressively increase the rate of admission of the cooled dewaxing solvent. The cooling coils are composed of pipes with progressively increasing diameters to avoid excessive increases in velocity in response to the addition of the progressively increasing solvent streams at successive inlets. A filter communicates with the relatively large end of the cooling coils to separate the approximately uniform wax crystals formed from the liquid solution.

U.S.P. 2,420,446. Petroleum Oil Compositions. A. G. Rocchini and C. B. Pattinson, Jr., to Gulf Research and Development Company.

The mineral oil composition comprises a major amount (e.g. 99.5 percent) of a petroleum lubricating oil, such as an oil with a viscosity of 150-450 Saybolt Universal seconds at 100° F., and a minor amount (e.g. 0.25-0.5 percent) of benzaldehyde phenylhydrazone sufficient to retard halogenation of the lubricating oil.

U.S.P. 2,420,893. Compounded Lubricating Oil. J. G. McNab and C. L. Fleming to Standard Oil Development Company.

A mineral lubricating oil is described which contains a minor quantity of a metal salt of a thiophosphoric acid ester of an octyl phenol sulfide as a stabilizer, e.g. a barium salt of a dithiophosphoric acid ester of a tert.-octyl phenol sulfide.

U.S.P. 2,420,953. Lubricant. R. A. Hunt to Standard Oil Company of Indiana.

A hydrocarbon oil normally tending to cause copper plating, i.e. the removal of copper from certain parts of the equipment and its deposition in other parts thereof, is compounded with a

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copper deactivator, such as the reaction product of an aromatic o-hydroxy aldehyde and an aliphatic polyamino compound with at least 2 primary amino nitrogen atoms, and tricresyl phosphate in small quantities. For example, 0.001-2 percent of the deactivator and about 3 percent of the tricresyl phosphate can be employed.

U.S.P. 2,421,004. Mineral Oil Composition. H. G. Berger and E. W. Fuller to Socony-Vacuum Oil Company, Inc.

The mineral oil composition comprises a viscous mineral oil fraction mixed with 0.5-10 percent of an oil-soluble salt of detergent properties, such as a metal sulfonate, and 0.05-5 percent of an oil-soluble product obtained by reaction of P_2S_5 and a hydrocarbon stock at a temperature of 125-200° C. for a relatively short time. The hydrocarbon stock employed in this reaction has an olefin content of 3-7 percent and an aromatic content of 40-60 percent. The P_2S_5 is employed in an amount of 1-8 percent by weight of the hydrocarbon stock. The corrosion and oxidation characteristics of an oil containing a metal sulfonate or the like, are greatly improved by addition of the P and S containing reaction product.

U.S.P. 2,421,040. Process of Obtaining Polar-Type Corrosion-Inhibiting Agents Soluble in Petroleum Lubricating Oils. J. E. Shields and E. V. Reilly to Alox Corporation.

Mixtures of substantially unsaponifiable oxygenated predominantly aliphatic and saturated hydrocarbons obtained from a petroleum fraction by its liquid-phase partial oxydation by means of an oxygen-containing gas are extracted with conc. H_2SO_4. Free H_2SO_4 is then separated from the resulting extract. The composition thus obtained, when blended with a lubricating oil, provides a lubricant of corrosion-inhibiting properties.

U.S.P. 2,421,082. Lubricant. M. Pier and F. Christmann vested in the Attorney General of the U. S..

The composition comprises a mineral oil lubricant and an oil-soluble viscosity increasing agent. This agent is a product obtained by the interpolymerization of a compound having a double C linkage (which compound, when polymerized by means of an acid-reacting inorganic halide, yields a product of m.w. above 1000) with a hydrocarbon mixture containing unsaturated constituents and consisting of cracking or dehydrogenation products of hydrocarbons or hydrocarbons obtained in the synthesis of gasoline from CO and H_2. For example, the viscosity increasing agent can be produced by interpolymerizing by means of BF_3 styrene, isobutylene and a mixture containing unsaturated hydrocarbons obtained by cracking paraffin wax at 500° C.

U.S.P. 2,421,421. Process of Treating High-Molecular-Weight Hydrocarbons. A. J. Hoiberg to Lion Oil Company.

A hydrocarbon of high molecular weight, such as a mineral lubricating oil or an asphalt, is blown in the presence of a metal halide salt, such as $AlCl_3$, $MgCl_2$, or $ZnCl_2$, and finely divided metal, such as Al, Mg, or Zn, with a gaseous stream containing free oxygen at a temperature of 400-550° F. An asphaltic product is obtained. The blowing operation is favorably influenced by the added chloride catalyst, while the free metal serves as a promoter.

U.S.P. 2,421,543. Lubricant. J. F. Cook to Union Oil Company of California.

The lubricant consists of a major amount of oils or greases and a small amount of a finely divided, non-crystalline metallic sulfide dispersed therein. Extreme pressure properties are imparted to the lubricant by this addition. For example, 1-10 percent of finely divided Sb_2S_5 or HgS, or SnS_2 can be employed as the additive.

U.S.P. 2,421,631. Lubricating Oil. B. H. Lincoln and G. D. Byrkit.

The lubricant comprises a major proportion of oil of lubricating viscosity and a minor proportion of a salt of a sulfurized relatively high molecular weight unsaturated carboxylic acid. The sulfurization of this acid is effected by Na_2S_5. The additive stabilizes the oil against oxidation. 0.001-10 percent of a salt of sulfurized soybean oil acids, corn oil acids, or oleic acid can, for example, be employed.

Refining Patents Made Available for Licensing

Various patents relating to refining, etc. have been assigned to the Secretary of Interior and are available for licensing, Washington has announced. Licenses are customarily issued on a non-exclusive, royalty-free basis. Applications should be made to the Solicitor, Department of the Interior, Washington 25, D. C., which explains that the Department does not have copies of patents for distribution but that they may be obtained from the Patent Office at 25 cents per copy. The list showing patent numbers, date and title follows:

2,118,829, 5/31/38, Preparation of Cobalt-Copper Catalysts.
2,215,484, 9/24/40, Sonic Flocculators and Method of Flocculating Smoke or the Like.
2,255,069, 9/8/41, Method and Apparatus for Separating and Concentrating Gases.
2,283,954, 5/26/42, Apparatus for Testing the Embrittlement Cracking Characteristics of Solutions.
2,283,955, 5/26/42, Means for and Methods of Testing Embrittlement Cracking Characteristics of Solutions.
2,297,538, 9/29/42, Liquid Oxygen Explosive.
2,297,670, 9/29/42 Method of Protecting Boilers and the Like Against Embrittlement.
2,362,500, 11/14/44, Apparatus for Testing Flame Safety Lamps.
2,366,184, 1/2/45, Production of Potable Water from Saline Solutions.
2,371,629, 3/20/45, Artificial Thermals.
2,395,902, 3/5/46, Electronic Chronoscope for Measuring Rates of Detonation.
2,410,043, 10/29/46, Process for Manufacturing Calcium Fluoride.
2,411,157, 11/19/46, Means for Collecting Gas Analysis Samples.
2,414,118, 1/14/47, Synthesis of Fluorene and Its Derivatives.

All Space Reserved for Chemical Industries Show

Space reservations already assure the complete occupancy of four floors of Grand Central Palace, New York, where the 21st Exposition of Chemical Industries will be held December 1-6.

The display of processing equipment will be more comprehensive than usual, with many new developments to be disclosed. Raw and fabricated materials, standard mill units, such as valves and piping, shafting pulleys, belts, clutches and couplings, transmissions, conveyors, motors, pumps and others will be shown in great variety, exposition officials declared.

NEW EQUIPMENT
. . . MANUFACTURERS' · LITERATURE . . .

FOR FREE COPIES OF MANUFACTURERS' LITERATURE OR MORE INFORMATION ON PRODUCTS DESCRIBED ON THESE PAGES, USE THE MAILING CARD INSERTED IN THIS ISSUE

1—Feed Water Control

J. A. Campbell Company, 645 East Wardlow Road, Long Beach, California, is offering equipment for control of boiler feed water through magnetic action. The device can be attached to a boiler together with a switch box.

It embodies a round ball float of Monel metal, capable of resisting pressure of 400 psi. This float carries a steel ring which attracts the magnets when the ring comes into their fields. Alnico permanent magnets are used, capable of lifting 100 times their own weight. A Micro-switch is used. When the level of water in the boiler lowers to a predetermined point, the magnetic action opens the water line, and when the level rises to a certain point, the feed line closes automatically.

Boiler Feed Control

CHECK THE CARD AT PAGE 208

2—Portable Cleaning Basket

A handy, four-wheel repair shop dolly for carrying machine and engine parts for the repair job to the wash rack has been introduced by Homestead Valve Manufacturing Company, Coraopolis, Pa. Known as the "Clean-Tote," the dolly is mounted on 4-inch full swivel, hard composition wheels. One model features an interchangeable, two-deck dolly with a shallow metal tray and a specially designed wire mesh cleaning basket with an auxiliary fine mesh basket for handling small, delicate machine parts. The other model consists of the same basket mounted on the same type of oversize caster wheels. A detachable "U" draw bar permits the dolly to be pulled or pushed without stooping.

The same company has developed a new type radiator flushing nozzle which fits all sizes of radiator hose and affords a positive hose seal without use of clamps, it is claimed.

CHECK THE CARD AT PAGE 208

3—Water Treating Chemical

Liquid Conditioning Corporation, 114 East Price Street, Linden, New Jersey, is offering a resin water softening zeolite, which has been worked out to give higher efficiency to this type of water treating chemical. The news release from the company offers this description of its Liquonex CR:

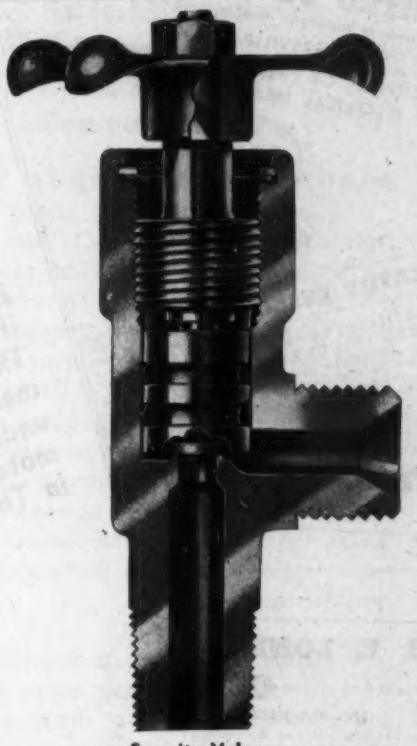
"This modern cation exchange material has a high capacity several times as great as some of the old-fashioned zeolites, and permits higher flow rates per square foot of area. It practically eliminates the hardness of a raw water, leaving only 0 to 2 parts per million of hardness, expressed as calcium carbonate, by the most rigid tests. A further important advantage of Liquonex CR is that it is non-siliceous or carbonaceous. Therefore, it does not impart silica to the treated water.

CHECK THE CARD AT PAGE 208

4—Safety Goggles

American Optical Company, Southbridge, Massachusetts, is offering a rubber frame safety goggle, especially designed for use in hot and humid atmospheres, where chemical and dust hazards exist. The new goggle is designed with an inhalation and exhalation valve to prevent fogging and steaming of the acetate single lens. When the wearer inhales air seeps through the chamber, removing moisture on the inner lens surface before it can fog. When exhaling the inlet valve closes, allowing moist air to escape through the exhalation valve.

CHECK THE CARD AT PAGE 208

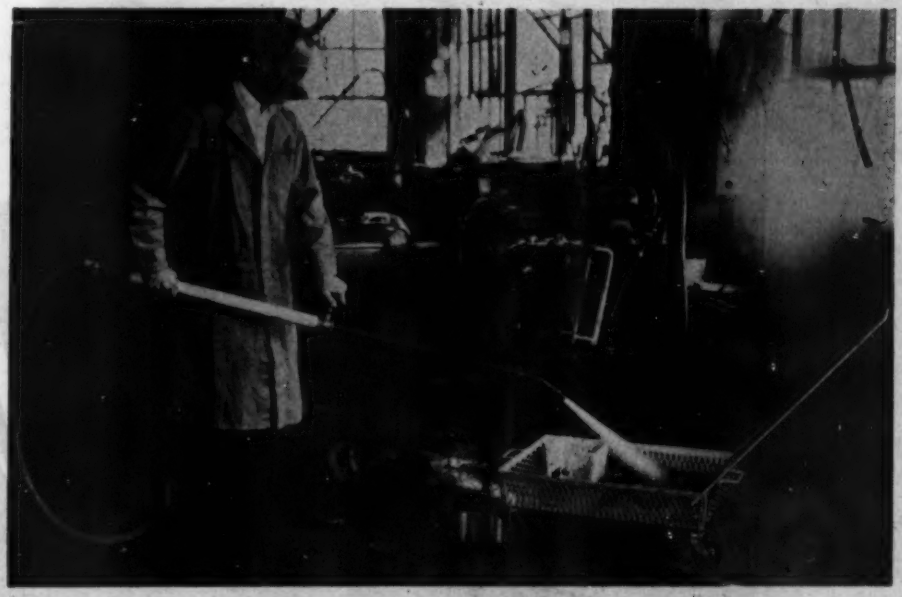


Security Valve

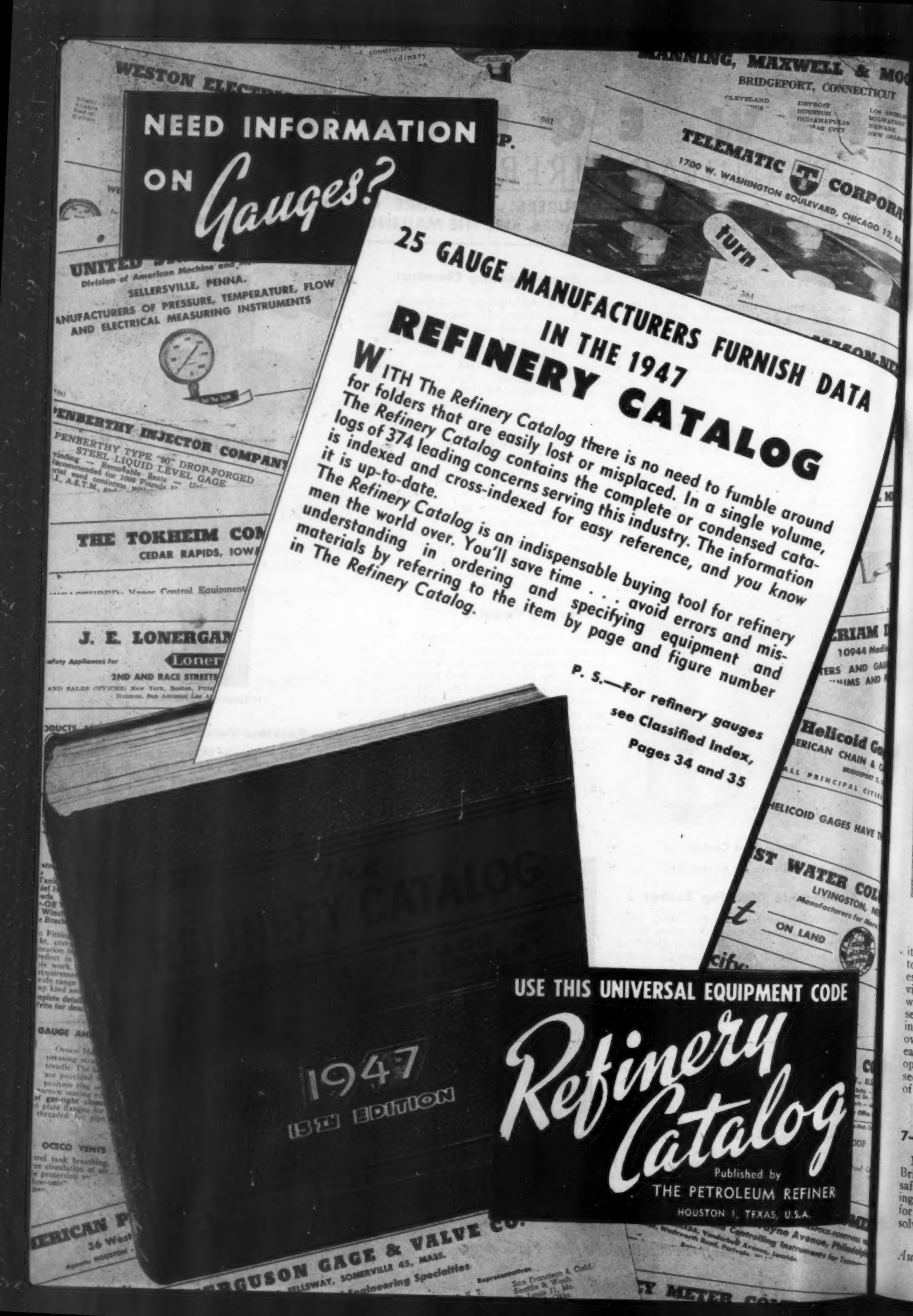
5—Packless Valve

Security Valve Company, 410 San Fernando Road, Los Angeles 31, has designed a packless steam valve, which is offered as a unit that will not freeze in either open or closed positions.

A brass retaining washer, held in



Clean-Tote Portable Cleaning Basket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25 GAUGE MANUFACTURERS FURNISH DATA IN THE 1947
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WITH The Refinery Catalog there is no need to fumble around for folders that are easily lost or misplaced. In a single volume, The Refinery Catalog contains the complete or condensed catalogs of 374 leading concerns serving this industry. The information is indexed and cross-indexed for easy reference, and you know it is up-to-date.
The Refinery Catalog is an indispensable buying tool for refinery men the world over. You'll save time . . . avoid errors and misunderstanding in ordering and specifying equipment and materials by referring to the item by page and figure number in The Refinery Catalog.
P. S.—For refinery gauges see Classified Index, Pages 34 and 35
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place by a Waldes snap ring, positively stops upward motion of the spindle at the wide-open position. Since the retaining washer is free to rotate, there is no possibility of the spindle becoming wedged in the open position. In the closed position, downward motion of the spindle is halted both by the valve's Neoprene seat and a metal-to-metal contact. Again, no freezing is possible, owing to the inherent resiliency of Neoprene. In the SE-CO valve gas pressure is ingeniously utilized to increase seal effectiveness. Increasing pressure against the exposed portion of the neoprene seat is translated into increasingly firm contact at the actual sealing points.

CHECK THE CARD AT PAGE 208

6—Time Cycle Controller

Seely Instrument Company, Inc., 377 Fourth Street, Niagara Falls, N. Y., announces its Model PB2 time cycle controller, an instrument which has been completely re-engineered after having undergone several years of commercial tests. Developed originally to control plastic and rubber molding equipment,

Seely Time Cycle Controller

it offers equal savings in operator effort to uniformity of product to batch processors in the chemical industry. It provides great flexibility of scheduling which can be varied at will. The time selector carries 150 keys to provide timing to within .67 of 1 percent of the over-all time range of the instrument for each successive event scheduled in the operation selector. Time and sequence sections are driven by gear-head motors of ample power.

CHECK THE CARD AT PAGE 208

7—Safety Valve

Manning, Maxwell & Moore, Inc., Bridgeport, Conn., is offering a new safety valve for air compressors, utilizing a nylon disc. This valve is designed for users of air compressors. Nylon solves the problem for a satisfactory

Pritchard's New Gas Treater
. . . the SULPHURSORBER
Converts SOUR GAS into USABLE FUEL
. . . Automatically
. . . Dependably
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. . . Conveniently
in any quantities, anywhere

If you want "sweet" gas at an isolated field location or want to treat large volumes at a central plant, Pritchard's Sulphursorber is the answer. These hydrogen sulphide removal units of the amine type deliver gas of any specified purity, regardless of how sour it may come from the well. Available in fully automatic, compact, *portable* design in a wide range of capacities, Sulphursorbers eliminate the daily servicing and hauled-in materials required by other gas sweetners.

Pritchard installations employing the same perfected principles in large-scale permanent plants are equally economical. Investigate the many Pritchard projects which have been operating over long periods of time and put this qualified team of veterans to work on your own gas problems, dehydration and cleaning as well as desulphurization. Pritchard offers not only the equipment developed from thorough experience but also the organization and facilities to design and construct for any requirements.

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GARLOCK Pipe Thread Compound is a superior material developed in the Garlock laboratories for application to threaded joints of pipe lines and other equipment handling steam, water, gas, air, hot or cold oil, gasoline, kerosene or alcohol.

You can depend on GARLOCK Pipe Thread Compound to make a permanently tight joint even under difficult conditions, as it will not harden, shrink or corrode. In fact, it protects joints from corrosion, rust and "freezing."

GARLOCK Pipe Thread Compound, ready to apply as it comes from the can, is handy to use and is economical—only a thin coating is required to make a joint. Does not spoil or deteriorate if kept in stock for long periods of time. Available in 2-lb., 4-lb. tin cans and in larger containers.

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Does Not Harden or Shrink

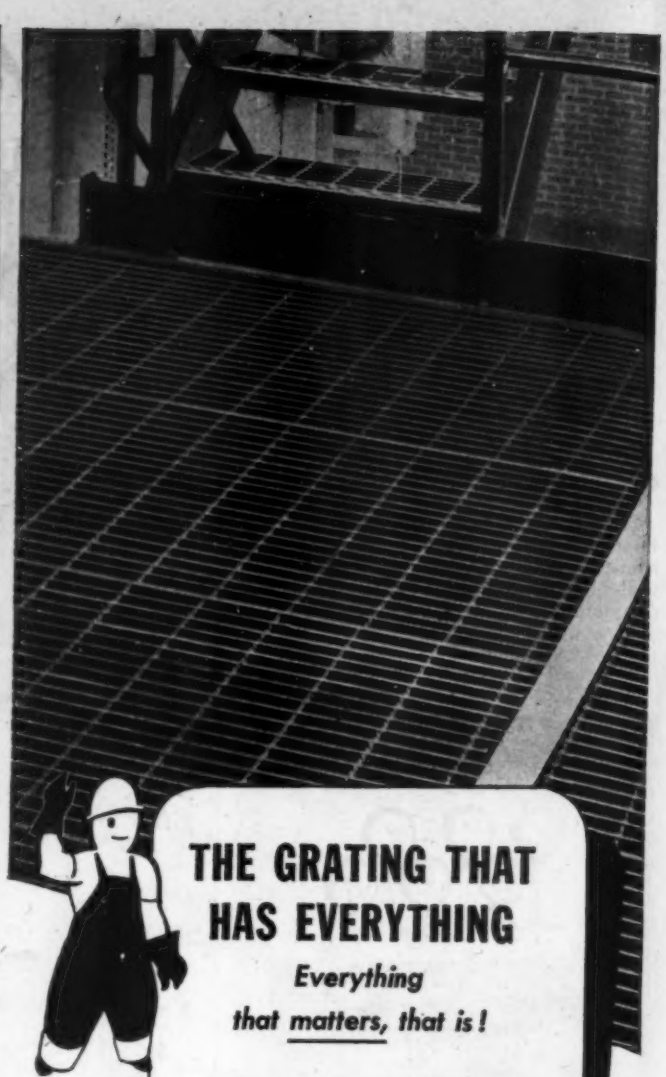
Keeps Joint from "Freezing"

Protects Against Rust and Corrosion

Does Not Drip

Does Not Spoil or Deteriorate

Garlock PIPE THREAD COMPOUND



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1. One-piece electroforged steel construction for guaranteed strength!
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For a "close-up" of Blaw-Knox Grating construction, write today, on your business letterhead, for this "paper-weight-size sample"

BLAW-KNOX DIVISION
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BLAW-KNOX
ELECTROFORGED STEEL GRATING

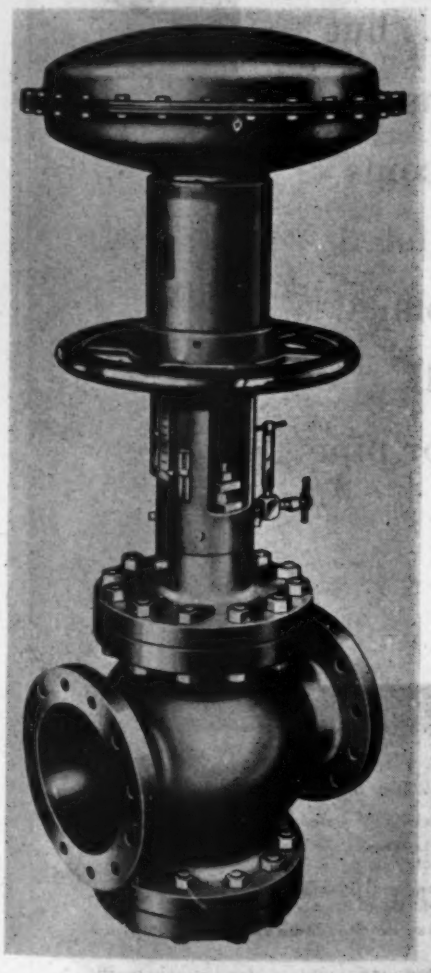
seat material because it possesses the essential characteristics of wear resistance, hardness, and flexibility, the manufacturers say. This new valve utilizes a nylon disc working against a bronze seat. Nylon, it is claimed, will not flow or creep under spring compression or stick or weld itself to the seat. It also has needed flexibility. The valve meets ASME requirements, is flow-tested and discharge capacities are guaranteed.

CHECK THE CARD AT PAGE 208

8—Handwheel Valve

The Hammel-Dahl Company, 243 Richmond Street, Providence 3, Rhode Island, has designed continuously connected handwheel valve, built integral with the superstructure of the control valve. The unit is powerful enough to operate the control valve manually, regardless of maximum instrument air pressure on the diaphragm or in opposition to the spring.

The design is offered as a means of eliminating the customary method of



Handwheel Valve

safeguarding diaphragm valves by installation of a by-pass assembly. The handwheel can be used to shut the valve tightly or to block it wide open.

The valve plug position indicator automatically indicates the valve plug position and shows the setting of the travel stops. It shows at all times the percent free travel of the valve plug and exactly in what portion of the valve stroke the travel can occur. It shows whether the handwheel is in a neutral position.

A full clearance window in the super-

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"DRIVE DEPENDABILITY", two key words in refinery operation. When you go "on stream" the power drive for your pumps, blowers and other equipment must not fail. Here the Troy-Engberg Steam Engine enters the picture—for complete dependability nothing surpasses the reciprocating steam engine. Ninety, 100, 150 days of continuous 24 hour operation is "normal" for a Troy-Engberg.

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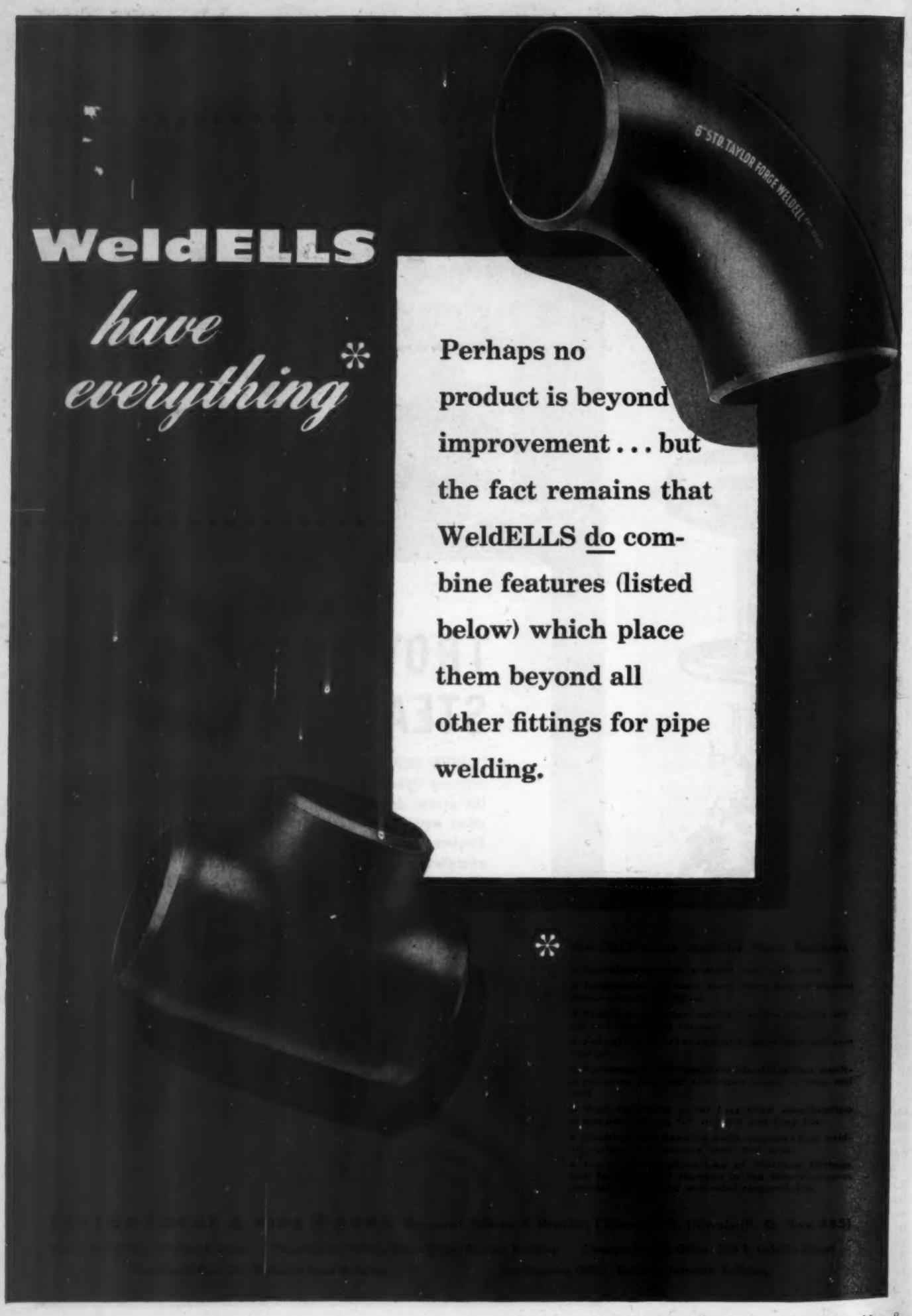
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Perhaps no product is beyond improvement . . . but the fact remains that WeldELLS do combine features (listed below) which place them beyond all other fittings for pipe welding.
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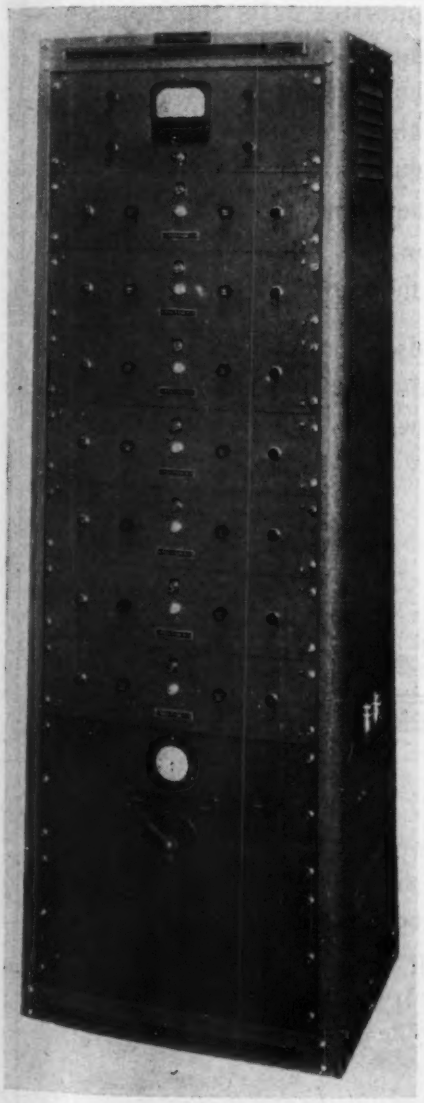
structure allows repacking or servicing of the packing box without disassembly. The handwheel may be applied to any Hammel-Dahl valve, sizes 2-inch through 12-inch.

CHECK THE CARD AT PAGE 208

9—Alarm Cabinet

Davis Emergency Equipment Company, Inc., 164 Halleck Street, Newark 4, New Jersey, has adapted its gas alarm system into a cabinet for use where limited floor space prevents installation of a standard panel board arrangement. This multiport system is designed for sampling from a minimum of six locations to a maximum of 12 locations. All remotely located analyzing heads are controlled from a single cabinet, occupying floor space 22 x 17¼ inches.

An installation consists of an analysing head in each area being sampled, and the control cabinet. The control cabinet is composed of a series of panels as shown in the illustration. On the top panel are mounted the meter, motor, main switch, alarm relays and push button controls. The other 7 panels are connected to individual analysing heads. In



Davis Alarm Cabinet

the base is mounted a sampling pump which is continuously drawing samples through all analysing heads. As the gas and/or vapor concentrations change, the

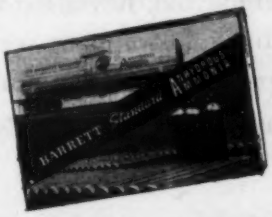
LOW-COST NEUTRALIZER FOR PETROLEUM REFINING

Barrett Anhydrous Ammonia, shipped as a concentrated liquid, with a guaranteed minimum purity of 99.5% NH_3, is one of the lowest cost neutralizing agents delivered to the refinery. Because of its low molecular weight, one pound of Ammonia will neutralize the same quantity of acid as several pounds of other neutralizing agents.

Easily vaporized, Anhydrous Ammonia follows the gas stream through the refinery equipment, neutralizing corrosive acids as they are formed. Ammonia has high solubility and a high rate of diffusion in oil.

Used in oil refining, Ammonia destroys acidity without the formation of water or undesirable emulsions. Products of neutralization can be easily removed from the oil. Excess Ammonia can be removed by blowing the oil with air.

Used as a liquid or as a gas, Ammonia is easy to handle in the refinery. For further information, communicate with the address below.



This interesting and helpful booklet is packed with useful information on Anhydrous Ammonia. You can obtain a copy without charge or obligation, by requesting it from the address below.

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Barrett

Looking Around

By THE OBSERVER

DIPLOMATS WITHOUT STRIPED PANTS

Whenever we plan a pipeline for carrying oil or gas from wells to tank farms, refineries, marine terminals or plants, our Real Estate and Right-of-Way Department clears its desks and prepares for a lot of work.

The right-of-way men consider what existing highways will have to be crossed, and what highway changes may be coming. They study railroad and other rights-of-way; cities, present or developing; irrigation and flood control projects. They find out who owns what.

Then they apply to the owners of the lands for permission to make the crossing, properly protecting all interests.

Our network of trunk pipelines in Southern California, the San Joaquin Valley and the San Francisco Bay Area is large. Some of it pierces closely built residential sections. Some of it traverses lonely stretches of desert.

To arrange for these crossings of other people's properties calls for statesmanship of a high order. It calls for fairness, tact and a sympathetic understanding of the other fellow's viewpoint. Our right-of-way men are diplomats in the finest sense, for they consider the landowner's interests as conscientiously as their own.

As long as our pipes lie in place on a right-of-way obtained across another man's property, we want to be regarded as welcome guests.

In many places we are landowners too. Reversing the situation, our right-of-way men reciprocate whenever possible by granting permission to others to cross our lands. It works both ways.

STANDARD OF CALIFORNIA

analysing head transmits a signal through an electric cable. Therefore, the response is instantaneous.

Each analysing head has its corresponding analyser panel. Through a program timer mounted on back of the cabinet, each analyser panel is consecutively connected with the top panel. This connection is maintained for 10 seconds for each panel. Thus, if six areas are being sampled, a complete tour of the areas can be made in one minute.

As each analysing circuit is connected with the meter and signal relays, a white pilot light on analyser panel is illuminated. This signal indicates that the percent of lower explosive limit of flammable gas or vapor can be read on the meter.

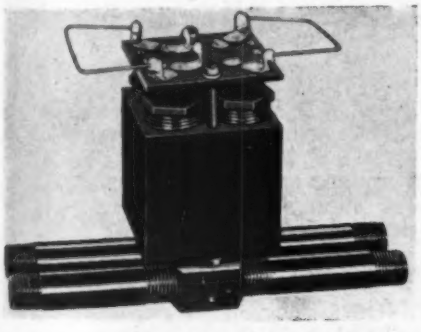
When flammable gas or vapor concentration reaches the alarm point setting, instantly a red pilot light is illuminated on the panel. Simultaneously an audible signal is sounded both in the cabinet and in the area. Provision has been made for stopping the timer to hold a panel in contact with the control panel for further observation of a hazardous condition. On the top panel are mounted push button controls for silencing the audible signals and extinguishing red alarm lights on individual analysing panels. Each analyser panel, with its connected analysing head is a complete bridge circuit. Each circuit has its own power pack and filament blow-out signal.

CHECK THE CARD AT PAGE 209

10—Gas Testing Unit

Gow-Mac Instrument Company, 22 Lawrence Avenue, Newark, New Jersey, has designed a thermal conductivity unit for the analysis and testing of gases.

It incorporates four filaments assembled in appropriate chambers and wired in a balanced bridge arrangement. Each of the four elements conforms to predetermined standards of resistance. When used with a suitable source of



Gas Testing Unit

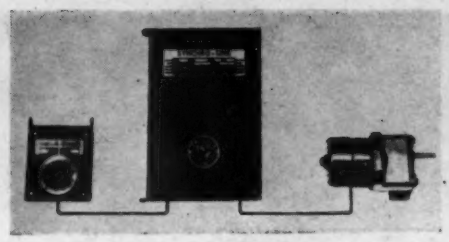
constant voltage the degree of unbalance of the bridge circuit provides an accurate measure of the relative thermal conductivity of an unknown gas or the quantitative variation in a known gas.

Typical applications include special atmospheres, gas synthesis, inert gas generation and distribution, efficiency of internal combustion engines and furnaces, and wherever hydrogen and carbon dioxide are found. Units may be used with indicating, recording or controlling instruments.

CHECK THE CARD AT PAGE 209

11—Motor Control

Yardney Laboratories, Inc., 105 Chambers Street, New York 7, has designed a control system for one or more motors through the setting of a master control



Yardney Motor Control

dial, the Synchro-Link, Type SL 3. Two adjustments are provided, a sensitivity control which is a three position switch to provide three steps of accuracy; and an anti-hunting control, a four-position switch for extending the range of anticipating over a suitable portion of the full range.

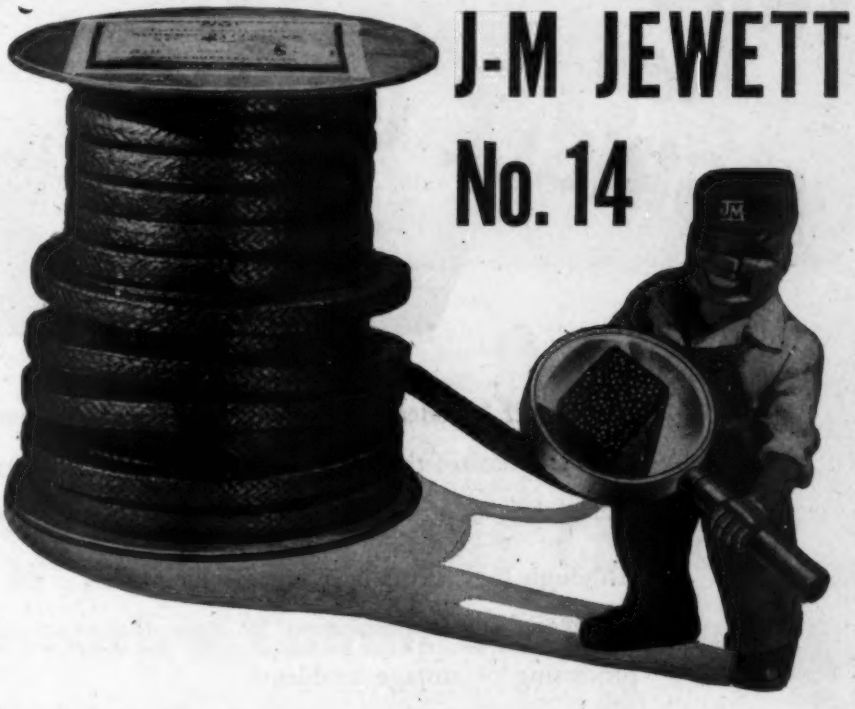
The control operates on the principle of a self-balancing electronic bridge. The master control can be located at any distance from the link controller up to several thousand feet. The device can be used for a variety of remote positioning operations. It will control the speed adjustment on variable speed transmission, the setting of motorized valves, volume dampers, engine throttles, pumps, and special machinery.

CHECK THE CARD AT PAGE 209

12—Tube Fittings

A new line of commercial tube fittings has been designed for heavy duty service by Flodar Corporation, 331 Frankfort Avenue, Cleveland, Ohio.

The manufacturer claims these fittings



One valve stem packing that

HOLDS ITS LUBRICANT

When temperatures pass 500 F, glands need not leak or valve stems bind. Pack them with J-M Jewett No. 14, it stays pliable in high-temperature service.

J-M Jewett No. 14 is impregnated with a special lubricant that will not run out at high temperatures. Made of asbestos stiffened with copper, it is braided jacket over jacket, then formed square. This construction combines maximum sealing with minimum friction.

Specify Jewett No. 14 for all your valve stems in high temperature service. At your Supply House or write Johns-Manville, Box 290, New York 16, N. Y.

Johns-Manville PACKINGS & GASKETS

The ever broadening scope of the General American organization through the years emphasizes the vast number of General American hands through which your plate fabrication problems must pass — from preliminary planning to the final details.

Although their skills are varied — their goal is the same — to give you precision-engineered plate fabrication to meet the exact requirements of your handling, processing or storage problems.

Whether it be a fractionating tower for a new plant, a Wiggins Conservation Structure to enlarge storage facilities, or a mixing tank to replace an obsolete unit, General American will design it, fabricate it, and, if desired, erect it in exact conformance to your specifications.

The name itself — General American — reminds you that thousands of skilled hands stand ready, willing and able, now as always, to provide you with specialized steel plate fabricated equipment.

Other General American Equipment

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  Crude • Gasoline • Propane
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GAT-X GENERAL AMERICAN

to be 21 percent heavier and stronger than fittings of similar size. These fittings are of special value on heavy duty or high-pressure applications. Made of steel and finished in cadmium plate, Flodar fittings are manufactured in sizes from ¼ to 1½-inch and are available in straight union, elbow, side tee, tube tee and cross, both male and female.

CHECK THE CARD AT PAGE 208

13—Aluminum Paint

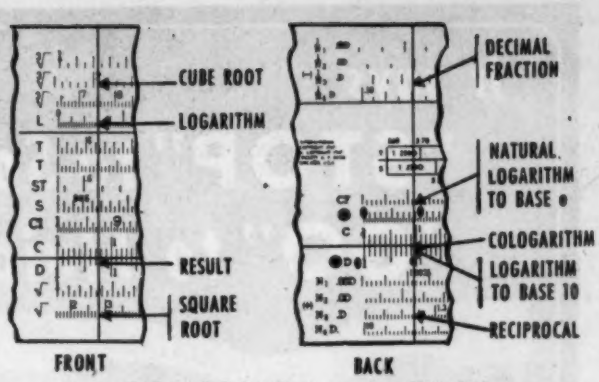
Prufcoat Laboratories, Inc., 63 Main Street, Cambridge 42, Massachusetts, is now offering its Prufcoat Aluminum for general maintenance painting. The product is made with synthetic resin and a special aluminum powder with excellent leafing qualities. During the war use of this paint was restricted to uses where prevention of corrosion was essential.

CHECK THE CARD AT PAGE 208

14—Deci. Log Log Slide Rule

A new deci. log log slide rule is announced by Picket & Eckel, Inc., 5 S. Wabash Ave., Chicago 3. The scales, on the front of the rule, are so arranged that only one setting of the hairline gives with each result its square root, cube root and logarithm. The log log scale on the back is expanded for greater accuracy, and arranged to give these five readings with each setting of the hairline: 1) decimal fraction to 4 and 5 figures, 2) its reciprocal to 4 and 5 figures, 3) logarithm, 4) cologarithm, 5) natural logarithm to base. The scales read from one ten billionth to ten billion, and give decimal point location. The slide rule is made of magnesium alloy with plastic surface bearing permanent, expanded, easy-to-read washable scales. Size is 12⅛ x 2⅛ x 3/16 inches. It comes complete with carrying case and illustrated instruction manual by Prof. M. L. Hartung, University of Chicago.

CHECK THE CARD AT PAGE 208



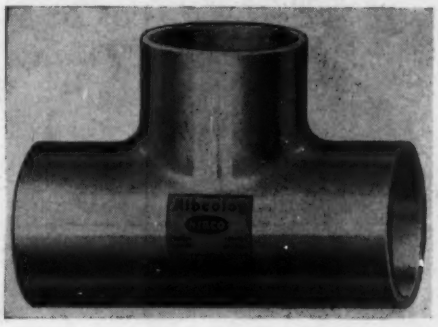
Pickett & Eckel Deci. Log Log Slide Rule

15—Turbulence Adapters

Northern Indiana Brass Company, Elkhart, Indiana, is offering a line of fittings, which are designed to overcome corrosion and turbulence problems in fluid processing services. They can be die formed from the tubing specified for the purposes of accompanying equipment and thus match perfectly with equipment design.

A lock ring allows joining with silver brazing or soft solder or the fitting may be butt welded. Fittings are available in 11 types, tees, elbows, reducers, adapters, and in a range of sizes from quarter inch to 4 inches O. D. Each fitting is identified with a permanent metal tag which gives necessary information for matching to specifications.

CHECK THE CARD AT PAGE 208



Strainer

16—Chemically Inert Gasket

The United States Gasket Company, 630 North 10th Street, Camden, N. J.,

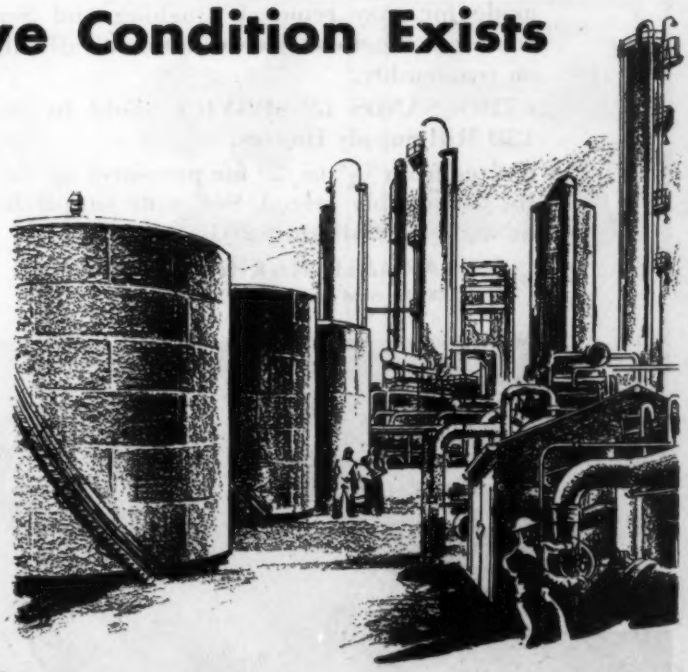
Use NUKEM *All Purpose* RESINOUS CEMENT

Wherever a Corrosive Condition Exists

Refineries use large amounts of NUKEM All-purpose Resinous Cement as a jointing compound for brick floors, pits, towers, sewers. It is especially valuable where high temperatures and/or alternating acid-alkali processes are involved.

NUKEM All-Purpose Resinous Cement is a synthetic, self-hardening, resinous compound. It is immune to practically all concentrations of commercial alkalies and acids, salts or solvents. It possesses new features of adhesion and resistance to wear. Delivering splendid service from the time it is first laid, it actually improves with age and exposure to heat and chemicals.

Our sales engineers will be glad to discuss your corrosion problem with you. You will find their experience and recommendations helpful. Write for Bulletin describing NUKEM All-Purpose Resinous Cement in detail.



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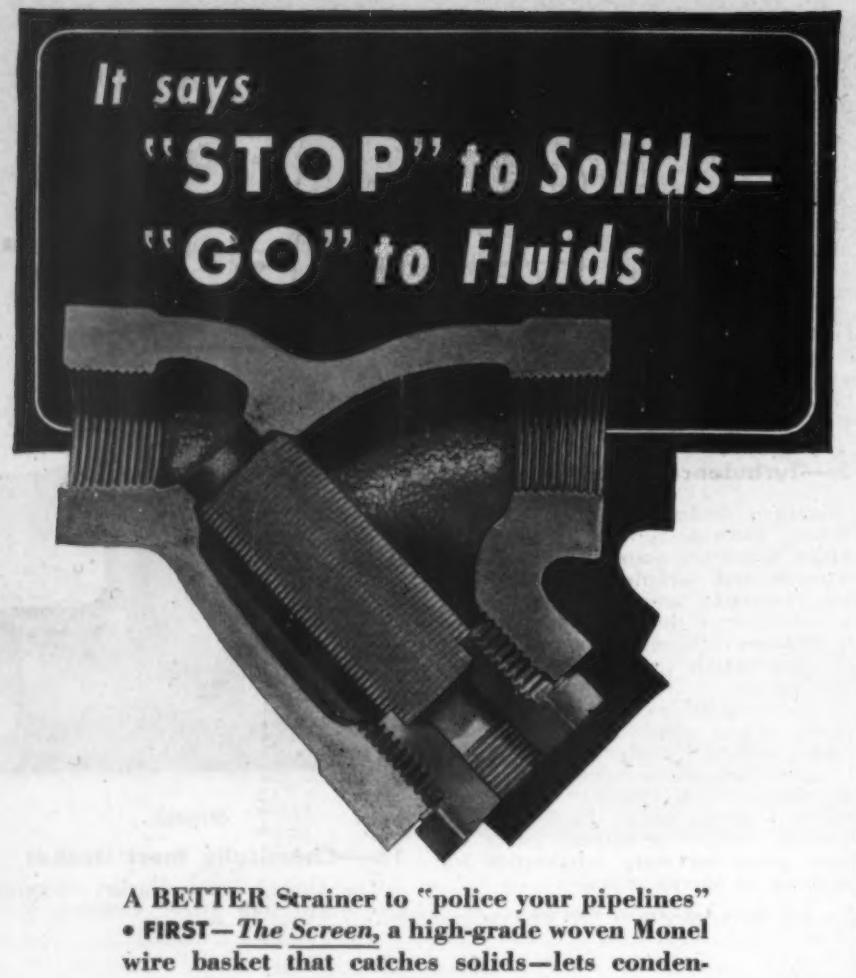

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• SECOND—*Finish.* Cadmium plated for protection against corrosion and for better appearance.

• THIRD—*Easily Cleaned.* Blow-off bushing made for easy removal. Bushing and Screen come out together. Screen automatically aligns on reassembly.

•THOUSANDS IN SERVICE—Sold by nearly 150 Mill Supply Houses.

6 sizes from ½" to 2" for pressures up to 600 lb. Reasonably priced. See your supply house or write for Bulletin S-201.

YARNALL-WARING COMPANY
128 Mermaid Ave. PHILADELPHIA 18, PA.

YARWAY STRAINERS

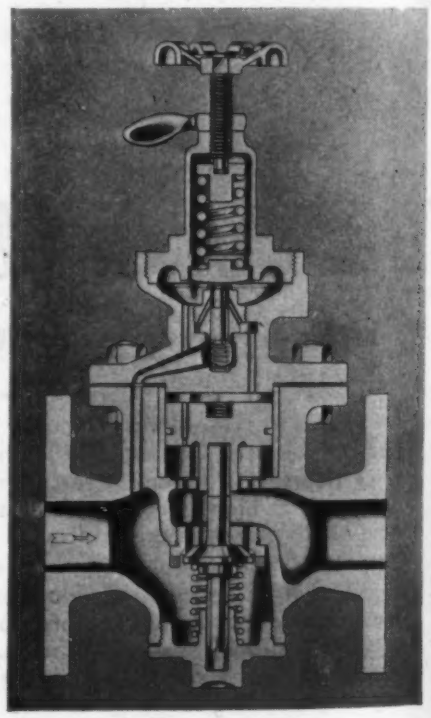
has made available a chemically inert gasket, "Chemiseal," by the application of special techniques which impart resilient characteristics to thermoplastic materials. The gaskets are fabricated from teflon (polyletraflouroethylene), which is fully resistant to the chemical action of materials such as organic and inorganic acids, bases, esters, ketones, aromatic hydrocarbons, halogenated solvents and acids. No known material, except melted sodium, and fluorine under pressure, reacts with them or causes any physical change. Temperatures ranging from —200° F. to + 500° F. can be accommodated without brittleness or decomposition. The gaskets never stick to flanges or become coated with process materials, it is claimed.

CHECK THE CARD AT PAGE 208

17—Unloading Valve

Leslie Company, 169 Delafield Avenue, Lyndhurst, New Jersey, has announced a throttling type unloading valve for use with steam, air or gas. This valve is said to be applicable wherever a throttling type regulating valve is required to maintain a constant inlet pressure by relieving the excess to a lower pressure system.

Construction features include bronze



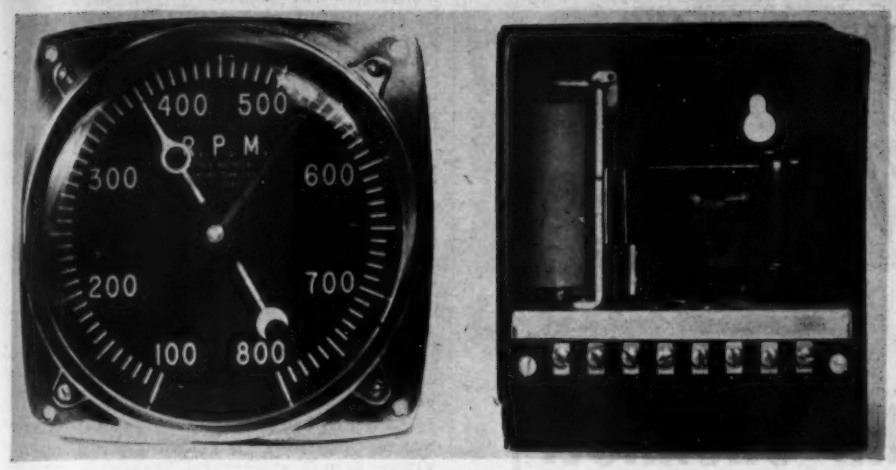
Leslie Unloading Valve

body, renewable wearing parts, hard-surfaced seat ring, hardened stainless-steel main and controlling valves, bronze piston, corrosion-resistant piston rings, phosphur-bronze diaphragm. It is available in sizes ½- to 4-inch; for inlet pressures from 25 to 300 psi, inlet temperature to 550° F., and pressure difference not less than 15 psi.

CHECK THE CARD AT PAGE 208

18—Tachometer With Control

A tachometer (Model 200) of the centrifugal type the readings of which are



Jones Tachometer

not affected by stray electrical curents or close proximity of large electrical units has been announced by Jones Motrola Corporation, 432 Fairfield Avenue, Stamford, Conn. The manufacturers claim that extreme temperature changes do not interfere with its operation and electronic control operates on a current flow of only 3-millionths amperes. The maximum speed of the equipment is controlled by setting the indicator hand and when this speed is attained, the equipment is shut off and a signal is given.

CHECK THE CARD AT PAGE 208

19—Aluminum Roofing

Production of a new, high-quality aluminum roofing material for industrial use, to be called Alcoa industrial roofing, has been announced by Aluminum Company of America.

The new product is a lightweight, heavy-duty specially-formed material, developed by Alcoa research "to meet the demand of industrial builders for an aluminum roofing and siding specifically adapted to factories, warehouses, storage depots, hangars, and similar structures." Alcoa states that the new roofing will carry heavy loads and meet exacting requirements of building codes.

Made from a special aluminum alloy, it carries exceptionally high resistance to industrial atmospheres, minimum maintenance and reduced roof load, and will have a covering width of 32 inches, allowing for a side lap of 1½ corrugations. It will come in standard five-foot through twelve-foot lengths, .032 inches thick.

Alcoa also announced that industrial aluminum siding, of the same alloy and lengths as the roofing, is going into production at the same time. The siding will have a coverage of 32 inches.

CHECK THE CARD AT PAGE 208

20—Flashlight

Approved by Underwriters' Laboratories, Inc., for Class 1, Group D, hazardous locations, this Rub-R-Lite "K2" flashlight operates on a new priciple with all working parts (including approved bulb-ejector mechanism) contained in a small "sealed-in-head" unit, which is "popped" in or out of the steel-lined neoprene case, whenever bulb or batteries are to be changed. It also in-

Rubber Flashlight

CHECK THE CARD AT PAGE 208

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troduces a one-button switch, guaranteed by the manufacturers for 10 years. The pre-focused "headunit" and batteries become sealed inside the neoprene rubber case, which gives longer life to batteries. The design and resiliency of the case permits much abuse. It is a non-conductor that can be used around high power lines and electrical equipment. There are no exposed metal parts.

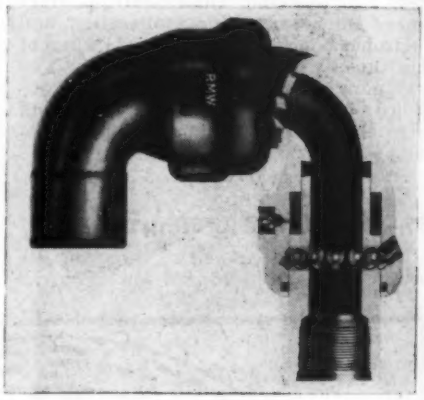
Lennan Lights, Inc., 231 West Olive Avenue, Burbank, Calif., is the manufacturer.

CHECK THE CARD AT PAGE 208

21—Swivel Joint

The Roofe Machine Works, 5415 Harrisburg Boulevard, Houston, has developed a high pressure swivel joint, which has applications in refining plant operation. It will withstand pressures in excess of 10,000 psi and has been designed for use in gas, gasoline, water and acid services. It will serve in hot oil service up to 600° F.

The unit will rotate the full 360 degrees and will swivel by hand at 50 percent of working pressure. Roller bearings provide line contact and greater working surfaces. Packing chambers are designed to allow lubricant to lift the lips of the packing when pressure is applied, so as to minimize the possibility of leakage. A gasket between the male and female members serves to resist abrasion from turbulence of liquid.



The units are being provided in sizes from 1-inch to 4-inch inclusive. Connections are threaded to API specifications, bored for welding or flanged. Lubrication is through high pressure fittings.

The company also has a similar swivel joint, rated from zero to 5,000 psi with working pressure test to 8,000 psi.

CHECK THE CARD AT PAGE 208

22—Electronic Link

Wheelco Instruments Company, 847 West Harrison Street, Chicago 7, Illinois, has published its educational bulletin No. 5 under the title "The Electronic Link," descriptive of automatic temperature control systems. The booklet deals with the function of electronics as a link between measurement and control. Charts and instructions for the selection of proper control systems are offered.

CHECK THE CARD AT PAGE 208

23—Steam Jet

Duriron Company, Inc., Dayton 1, Ohio, gives a description of its Durco

corrosion-resistant steam jet in Bulletin 1804. A chart is included which is for the assistance of engineers in calculating the proper size jet in steam consumption. Complete data on sizes and capacities, dimension drawings and a section on how to install and operate the equipment is a part of the bulletin.

CHECK THE CARD AT PAGE 208

24—Permanent Magnets

A booklet on G-E permanent magnets has just been issued by the Metallurgy Division of the General Electric Chemical Department, Pittsfield, Mass.

The booklet gives all general information on permanent magnets as well as technical data on characteristics, design, properties and applications of the G-E material.

CHECK THE CARD AT PAGE 208

25—Statometer

Davis Emergency Equipment Company, Inc., 45 Halleck Street, Newark, N. J., describes in Technical Bulletin 1141 its instrument called a "Statometer," designed for the study of static conditions in a plant. It is portable, battery operated and when not in use the air terminal is stored in the cover.

CHECK THE CARD AT PAGE 208

26—Tube Fabricating Equipment

A newly issued Catalog 401 describes Parker production tube bender and accessories, hand benders, cutters, flaring tools, beading kit, and tube fabricating service. Helpful operational information and pictures illustrating tools in use are included in the catalog available from The Parker Appliance Company, 17325 Euclid Avenue, Cleveland 12, Ohio.

CHECK THE CARD AT PAGE 208

27—Steam Engines

Bulletin 307 of Troy Engine & Machine Company, Troy, Penn., describes the horizontal types of Troy-Engberg steam engines, and presents sectional drawings of Type H, flat and piston valve as well as engineering data, and construction details. This bulletin or information relating to generating sets or vertical type engines will be sent upon request.

CHECK THE CARD AT PAGE 208

28—Laboratory Refrigeration

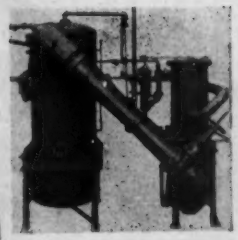
King Refrigeration Company, La Crescent, Minn., lists its laboratory refrigeration equipment in a new bulletin. Test cabinets and thermostat-controlled and automatic distillation apparatus for petroleum products are featured.

CHECK THE CARD AT PAGE 208

29—Steam Cleaning Machine

White Engineering & Manufacturing Company, Inc., 150 W. Passaic Street, Rochelle Park, N. J., has issued a folder describing its new model No. 46B White vapor steam cleaner designed for clean-

NOW is the TIME to consider next summer's



COOLING REQUIREMENTS

Too bad, but it's too late to order a CHILL-VACTOR for use this summer. If this equipment could be stocked on shelves we'd be glad to ship your order tomorrow. Trouble is, it takes three or four months to design, build and ship a complete CHILL-VACTOR Unit.

That is why you ought to start thinking NOW about ordering your CHILL-VACTOR for next Summer's cooling requirements. You should begin now to assemble your data, check your capacity requirements, and be ready to specify equipment which will provide maximum benefit.

CHILL-VACTOR equipment answers the need of chemical and process industries for:

Maintaining proper temperatures in certain solutions.

Chilled water for air conditioning.

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Special cooling requirements.

The Croll-Reynolds CHILL-VACTOR is one of the most dependable and efficient units available for many cooling requirements in the range above 32° F. It has no moving parts other than a standard chilled water circulating pump. Water is the only refrigerant.

Maintenance and repair costs are practically nil. Operating costs are usually less than for other types of refrigerating equipment where ample condenser water is available.

Inquiries will receive the careful attention of engineers with many years specialized experience in the field. An engineering survey can be arranged without cost or obligation.

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Edited by

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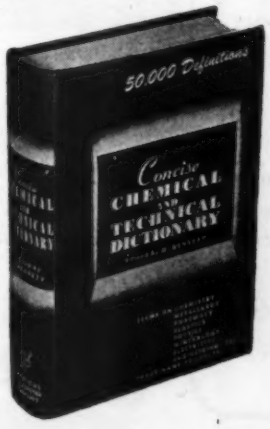

Every possible effort has been made to obtain accurate and up-to-date information, to make each entry authoritative. All the data for a given compound, all definitions are given in compact paragraph form, each main entry being printed in bold face type, so that the desired term is easy to locate on the page.

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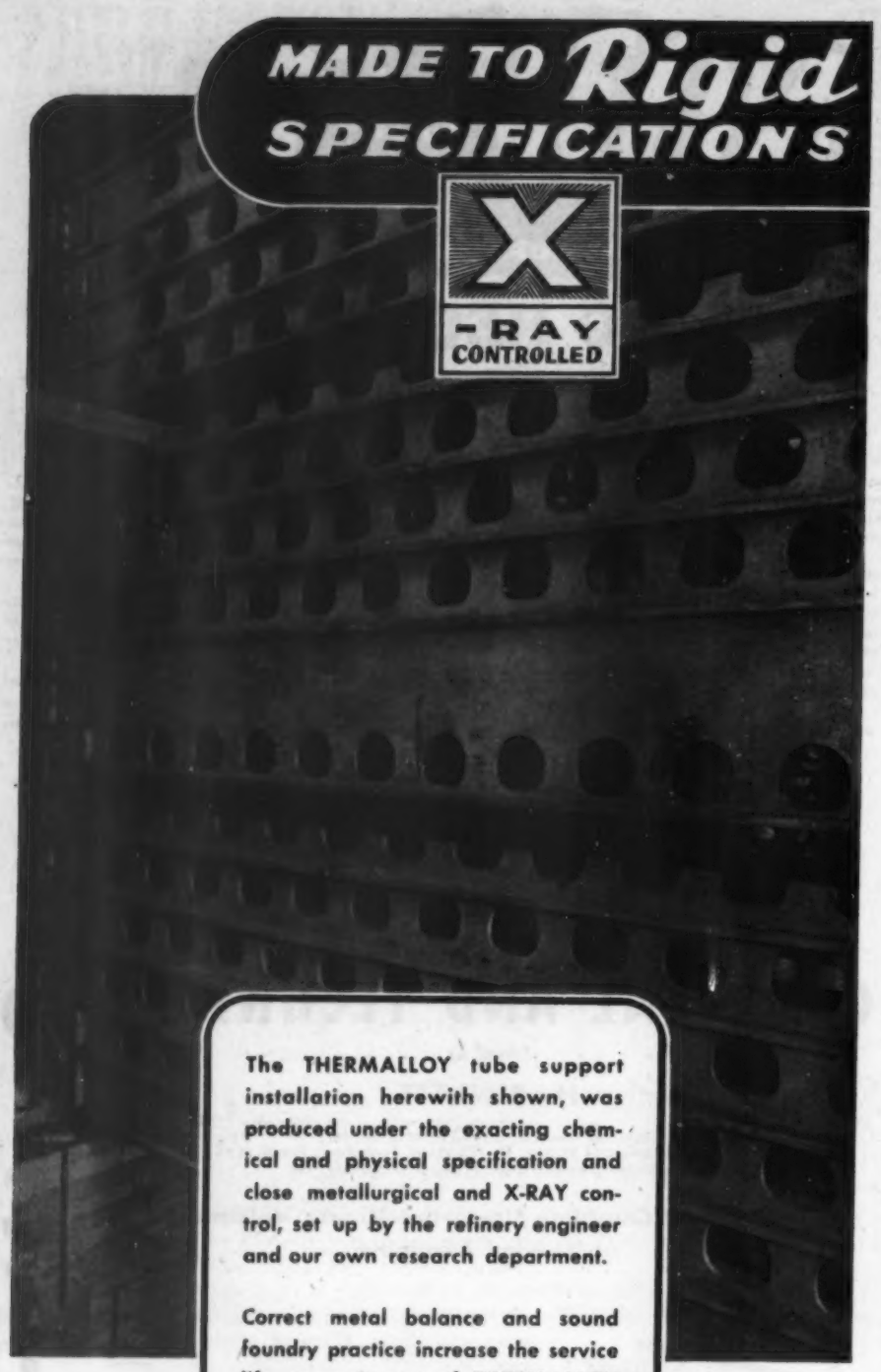

The THERMALLOY tube support installation herewith shown, was produced under the exacting chemical and physical specification and close metallurgical and X-RAY control, set up by the refinery engineer and our own research department.

Correct metal balance and sound foundry practice increase the service life per unit cost of THERMALLOY tube supports.

THERMALLOY is heat and corrosion resistant with satisfactory load carrying strength for maximum heat hour service at temperatures up to 2000° F.

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ELYRIA, OHIO.

ing trucks, buses, automobiles, road and construction machinery, railroad, marine and general industrial equipment. A diagram shows all the parts of the cleaner, drawing attention to the minimum number of operating valves, etc.

CHECK THE CARD AT PAGE 208

30—Regulator

Bulletin 471 issued by Northern Equipment Company, Erie, Penn., describes the Copes Type P regulator for remote boiler feed water control, both by illustration and schematic drawings. Simple level control and flowmatic control are detailed with full specifications.

CHECK THE CARD AT PAGE 208

31—Steam Specialties

Wright-Austin Company, 315 West Woodbridge Street, Detroit 26, has a new bulletin on steam specialties, No. 715. It offers representative types of steam traps, separators and boiler trimmings from the complete line. It describes three steam traps and three separators and gives brief descriptions of 22 other products.

CHECK THE CARD AT PAGE 208

32—Small Tools

Plomb Tool Company, 2009B Santa Fe Avenue, Los Angeles 54, has issued Bulletin 4728, which describes its complete line of pliers, adjustable wrenches and pipe wrenches. These tools are manufactured in the new plant which the company bought from J. P. Danielson Company, Jamestown, N. Y. The bulletin describes 24 pliers, 12 adjustable wrenches and 6 pipe wrenches.

CHECK THE CARD AT PAGE 208

33—Adjustable V-Belt

Manheim Manufacturing and Belting Company, of Manheim, Pennsylvania has issued a Veelos V-belt catalog which describes features of their adjustable V-belt, construction details, and installation methods. Engineering data and photographs showing application in a variety of installations are included.

The catalog will be sent on request.

CHECK THE CARD AT PAGE 208

34—Jigs and Fixtures

Reprint (ADR-42) "Jigs and Fixtures for Sheet Metal Welding," is available from Air Reduction Sales Company, 60 East 42nd Street, New York 17, New York. Metal joining processes applicable to the sheet metal field and simple jigs and fixtures, and more complex jigging problems, are all covered.

CHECK THE CARD AT PAGE 208

35—Liquid Level Controllers

Fisher Governor Company, Marshalltown, Iowa, has issued Bulletin F-1A describing its new type 2405 pilot or relay which incorporates new micrometer type level-setting and one adjustment only for specific gravity and proportional band setting.

CHECK THE CARD AT PAGE 208

ABOUT OUR AUTHORS . . . . . and Other PERSONALITIES

Standard Development Names Murphree Head

E. V. Murphree, executive vice president, has been elected president of Standard Oil Development Company, central research organization of Standard Oil Company (New Jersey), to succeed Robert P. Russell, who is resigning to become technical consultant to International Basic Economy Corporation of 30 Rockefeller Plaza, New York.

Murphree, who joined Jersey Standard 17 years ago, has contributed extensively to technical literature. Company developments in which he has had a part include the fluid catalytic cracking process; a process for synthesizing toluene which enabled unprecedented output of this component of TNT; and a catalytic process for making butadiene from petroleum for synthetic rubber.

During the war Murphree served with the Office of Scientific Research and Development as a member of the S-1 Executive Committee headed by J. B. Conant. The committee was instrumental in the established in August, 1942, of the Manhattan Project which developed the atomic bomb.

Russell, who joined the Development Company in 1927, became vice president in 1934 and president in 1944. For outstanding service during the war, particularly in the Development Company's work in the fields of flame-throwers, incendiary bombs, and smoke generators, Russell received the Medal for Merit, highest United States award to a civilian, and the Medal of Freedom for conspicuous services in connection with military operations in a war theater.

E. V. MURPHREE

Read Is Author of "Refinery Planning"

Davis Read, a member of the commercial development department of Universal Oil Products Company, was graduated from Purdue University in 1936 with a B.S. degree in chemical engineering. Upon graduation he joined the Reilly Tar & Chemical Corporation of Indianapolis, leaving in 1937 for a year of study at the University of Michigan, leading to an M.S. degree in chemical engineering.

Read, who joined Universal in 1938, is the author of "Refinery Planning," which appears on page 73 of this issue. His work with this company has been in various phases of research and development, including pilot plant investigations.

In the service department during 1943-1945 he was engaged in the operation and supervision of 100-octane gasoline plants which were Universal's responsibility in the war program.

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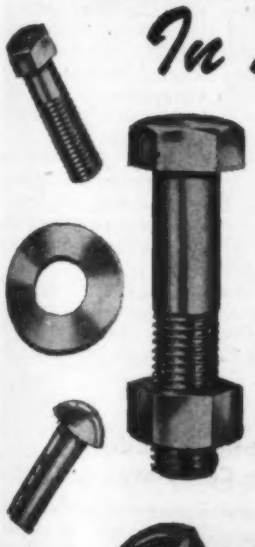

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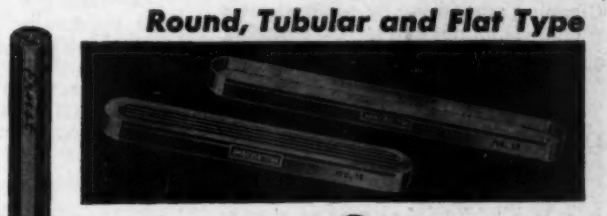

Fig. 12

RUBBER GAGE GLASS GASKETS
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Fig. 21 Fig. 22

Other Ernst Specialties
are given in Catalog No. 48 P

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Fig. 44

Fig. 13

Leakless Super Try Cocks, Bronze and Forged Steel Construction

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8-hr. non-stop TWO-gun cleaning or paint-stripping without refueling

Fully automatic pressure and temperature safety controls

Cleaning compound by-passes heater coils . . . no danger of clogging

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TRAILER-MOUNTED UNIT: Rugged, spring-suspended trailer chassis has pneumatic tires, sturdy steel tow frame. Unit is furnished with ¾ hp, 110-220 v. ac motor or, if power supply unavailable, with self-contained gasoline engine. Immediate deliveries. Free Folder illustrates both stationary and portable models.

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About EQUIPMENT—SERVICE Suppliers

David Gordon Company Sets Up New York Offices

David Gordon & Company, Inc., chemical, mechanical, and industrial engineers, have established offices at 29 Broadway, New York, and announce the election of David M. Gordon to the presidency. The new company will engage in chemical and mechanical design and consultation, and is currently reported active in domestic and foreign projects.

Gordon

Gordon, who received his chemical engineering education at Columbia University, has previous engineering experience with The M. W. Kellogg Company and with Interchemical Corporation, and is a member of the American Institute of Chemical Engineers, and the American Society of Mechanical Engineers.

Carr Brothers Company To Represent Hammell-Dahl

Carr Brothers Company, Boston, has been named New England Sales representative for Hammel-Dahl Company, Providence, Rhode Island.

The firm is composed of Frank J. Carr and Arthur T. Carr, brothers, who have set up a sales organization to represent manufacturers of industrial equipment in a territory they have previously serviced as representatives and sales engineers.

Through an inadvertance in last month's issue, Carr Brothers headquarters was shown as Houston instead of Boston.

Named Southwestern Manager

Addison Y. Gunter has been promoted to southwestern district sales manager for Alco Products Division of the American Locomotive Company. He will have headquarters in Houston.

Gunter

Gunter is a graduate of Texas Agricultural and Mechanical College, who has been in the Alco organization since 1937. He has served as production engineer, chief operations engineer, director of development and assistant manager of sales and engineering.

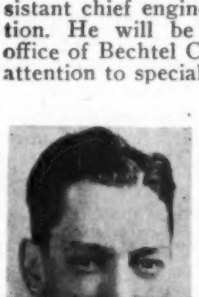
Following graduation, he was connected with the Cities Service organization for 12 years. He held positions in its refining plants and offices in Tulsa, Ponca City and East Chicago, where he was assistant manager of the refining plant.

Two Appointments to Bechtel Organization

Bechtel Corporation, San Francisco, has announced the appointment of A. J. Orselli as general manager of construction and the association of R. G. Aldridge with its engineering division.

Orselli has been with the organization since 1933. Since 1937, except for two years in shipbuilding work, he has been active in the construction of refining and chemical plants. In his new position he will have full responsibility for the firm's refinery construction.

Aldridge formerly was chief engineer of the manufacturing department of Union Oil Company and later was assistant chief engineer of Fluor Corporation. He will be in the Los Angeles office of Bechtel Corporation and devote attention to special projects in that area.



Jenkens

Christensen

Two Promotions Announced By Marley Company, Inc.

Ray T. Jenkens, who has been general sales manager of the Marley Company, Kansas City, since 1944, has been appointed assistant general manager. His promotion brought advancement for Lyle A. Christensen, who moves up to the post of general sales manager.

Jenkens has been with the Marley company since 1933 when he became a sales engineer. Before going to headquarters as general sales manager he was in charge of the Dallas, Tulsa and Houston territories.

Christensen goes to Kansas City after five years as sales engineer in the New York office. Previously he was with Ingersoll-Rand Company in its sales department.

Three Promotions Made In Aluminum Company

With the retirement of George J. Stanley, general sales manager of Alcoa, three assistant general sales managers for Aluminum Company of America have been elected vice presidents, Ralph V. Davies, Robert B. McKee and Donovan Wilmot. Davies succeeds Stanley in the Alcoa post.

Davies came to the Aluminum company in 1919 as a metallurgist at the New Kensington works. In 1922 he was transferred to Rochester in the sales office. Later he held sales posts in Buf-

falo, Washington and finally manager of the New York sales office in 1930. In 1943 he became product manager for ingot sales at Pittsburgh and in 1944 became assistant general sales manager in charge of sales engineering and sales development activities.

McKee has been with the company since 1915 when he joined its purchasing department. From 1919 until 1923 he was in sales work in the New York office, after which he was transferred to the Edgewater works. In 1930 he came to Pittsburgh headquarters as product manager for tubing and extrusion sales and was promoted to assistant general sales manager in 1944 in charge of district sales offices.

Wilmot became a member of the Alcoa staff in 1912 at New Kensington and was made general sales manager of the Aluminum Seal Company, a subsidiary, in 1915. In 1919 he went to the Boston office and in 1920 became manager of the Rochester office. After other duties in district offices and plant he became product manager for ingot sales in 1941 and an assistant general sales manager in 1944.

Stanley retired after 42 years with the company in both sales and engineering activities. He will continue, however, as a director. His first work was with the Pittsburgh Reduction Company, as Aluminum Company of America was in its Boston sales office in 1905. The next year he shifted to the engineering department and was placed in charge of electrical design for the Niagara Falls power house. Two years later he returned to sales work. After duty in New York and other offices he came to Pittsburgh in 1928 as general sales manager. Three years later he become vice president and in 1939 he was elected a director.

Ethyl Corporation Appoints Murdock to Sales Assistant

Malcolm P. Murdock has been appointed assistant general sales manager of Ethyl Corporation and according to Harry W. Kaley, vice president, his work will be to coordinate customer relations and services.

Murdock

Murdock, a graduate of Cornell University, joined Ethyl Corporation in 1933 as a field representative in the New York division, serving later as a clinic manager, and as assistant manager of both the Los Angeles and Chicago divisions. For the past two years, he has occupied an executive sales post with the Ethyl Specialties Corporation.

Fabimore Equipment and Controls Company Formed

Fabimore Equipment and Controls Company, Inc., formed January 1, 1947, is now active in sales and engineering activity, especially in valves and control equipment, headquarters, 5235 West North Avenue, Chicago 39, Illinois. Among the companies it represents in the Chicago-Milwaukee area are Kieley & Mueller, Inc.; Continental Equipment Company; J. A. Campbell Company; Photoswitch, Inc.; Wedgeplug Valve

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BREA, CALIFORNIA
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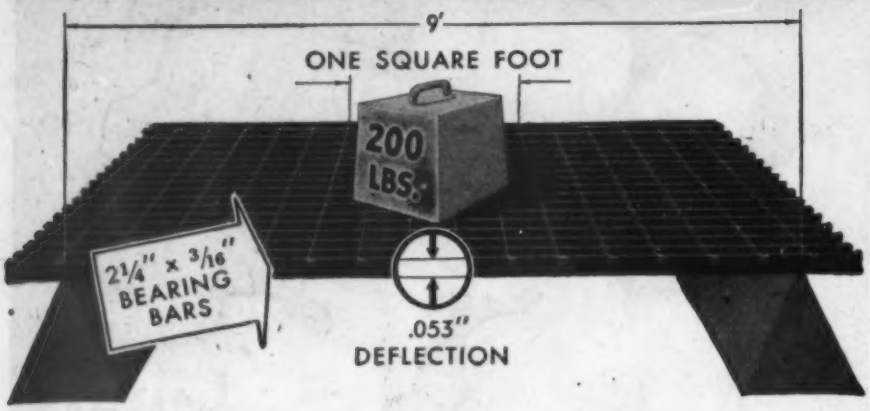

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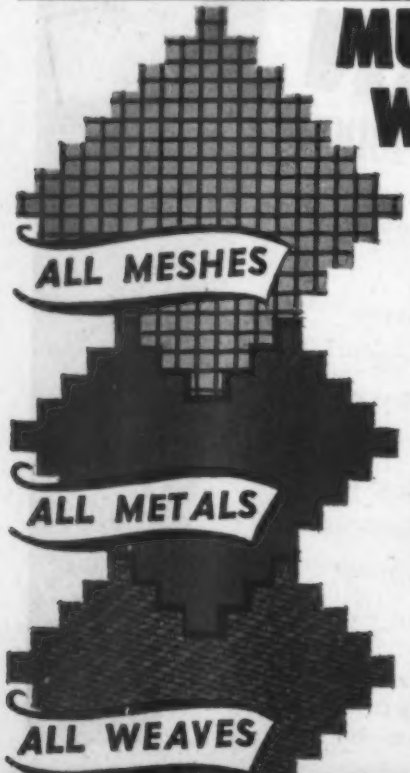

During its more than 35 years of constant service to scores of process industries, Multi-Metal has painstakingly built up the most extensive of all lines of wire cloth. Many special types have been developed for specific processing operations, and it is often possible to greatly increase the efficiency of existing installations by changing to one of these exclusive Multi-Metal patterns.

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Wire Cloth in Fabricated Units or by the Roll and the Cut Piece

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Company and Newark Boiler Regulator Company.

M. C. Waterman is president of the concern. He is a graduate of the University of Wisconsin. After spending three years with Minneapolis-Honeywell Regulator Company he was for 11 years with McAlear Manufacturing Company in sales and engineering work.

C. W. Snyder, vice president, is a graduate of the Missouri School of Mines, who was with Hanlon-Water, Inc., for 12 years and later was general sales manager of the combined operating group known as McAlrea Division of General Finance Corporation.

Frank T. Bock, secretary-treasurer, previously was with Johns-Manville Company, Chapman Valve Manufacturing Company and later with McAlrea Manufacturing Company.

Jack Knight Heads Sales For Reed Roller Bit Company

Jack F. Knight has been promoted to manager of the sales department of Reed Roller Bit Company. He will have charge of all sales promotional activities within the company and among customers.

Knight

He joined the Reed organization in the shipping department at Houston after graduation from the University of Texas. Shortly afterward he was advanced to a field warehouse post.

Next he went into sales work in the field, serving successively in various major oil fields. Later he was assigned to supervisory control of finished goods and then to production manager. In 1945 he became assistant sales manager, serving under R. G. Hamaker, vice president, who will continue to direct all sales activities.

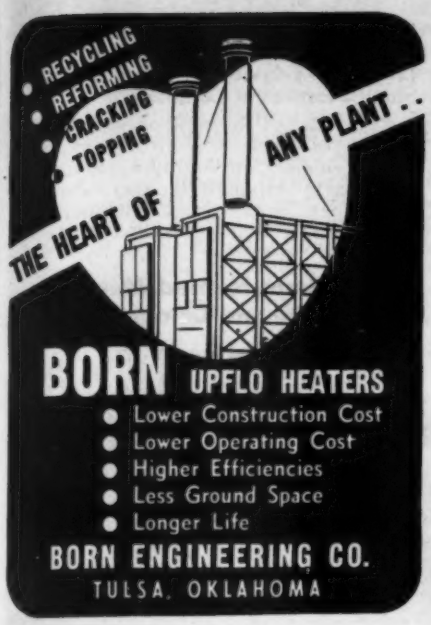
William Ludvik Now Heads McAlear Manufacturing Company

William Ludvig has taken over management of McAlear Manufacturing Company, Chicago, which is again an independent manufacturing company following its separation from the several companies which made up the Climax Corporation.

Ludvig, who is president and general manager, was associated with the concern almost from the time it was founded by James A. McAlear, 30 years ago. He was its vice president and general manager prior to its absorption into the Climax organization in 1943. The company manufactures automatic control equipment with plant and headquarters at 1901 South Western Avenue, Chicago.

Gang Succeeds Thompson As Ludlow Valve President

Oliver F. Gang has been elected president, director and general manager of Ludlow Valve Manufacturing Company, Inc., succeeding Alfred W. Thompson, who becomes chairman of the executive committee and continues as treasurer of the company. This announcement was made by Livingston W. Houston, chair-



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man of the board, following a July 1 board meeting.

Gang comes to the Ludlow company from the William Powell Company of Cincinnati and New York, manufacturers of valves, where until June 30 he was vice president and consulting engineer. From 1919 to 1931 he was sales engineer for the Lunkenheimer Company of Cincinnati, valve manufacturers. During World War II, he was a member of the valve and fittings industry advisory committee of the War Production Board. He is a veteran of World War I, and a mechanical engineer alumnus of the University of Cincinnati, class of 1919.

Thompson joined the Ludlow company in 1935 as vice president and succeeded Livingston W. Houston as president in 1939.

Wenzel

Coffey

Globe Steel Tubes Makes Sales Personnel Changes

T. R. Coffey, who has been manager of sales in the Wisconsin office of Globe Steel Tubes Company, has been promoted to the post of manager of sales and will have his office in the General Motors building, Detroit.

His promotion brought the advancement of manager of the Wisconsin office to D. F. Wenzel, who will have headquarters in Milwaukee.

Coffey has been in the sales department of the company since 1928 and was manager of the Wisconsin sales office from 1943 until his promotion this year. Wenzel has been in the general sales office of the company for 11 years.

Air Reduction Oxygen Plants For Decatur and Baton Rouge

Another oxygen manufacturing plant has been added to Air Reduction's chain with the opening of a new plant at Baton Rouge, La.

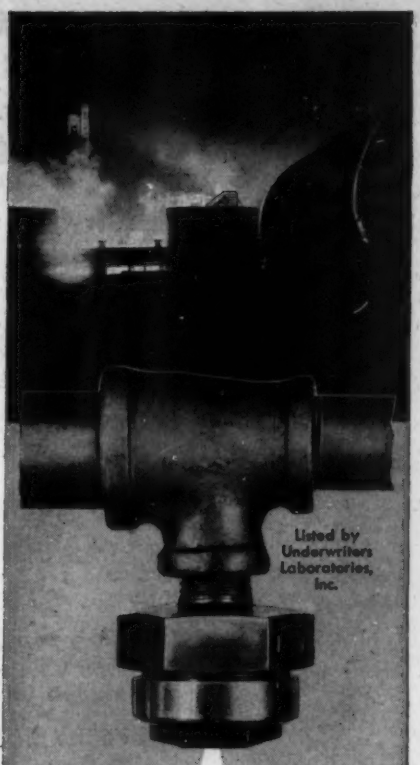
The plant superintendent will be J. L. West who has been with Air Reduction for 25 years. He was plant superintendent of the Airco oxygen plant at Shreveport, La., until his recent transfer.

Air Reduction also has opened a similar oxygen plant in Decatur, Ill., with George H. Klingenburg, as superintendent. Klingenburg has been with the company for 20 years.

Hiermeier Heads Subsidiary Of Honeywell in Mexico City

Minneapolis-Honeywell Regulator Company has formed a subsidiary company in Mexico, Honeywell-Brown, S. A., with hearquarters in Mexico City.

Virgil H. Hiermeier, manager of the Mexican company, prior to his promotion, served as manager of industrial instrument sales in Honeywell's St.



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Louis office. Hiermeier joined the Chicago staff of Honeywell in 1940, after 14 years of instrumentation work with Shell Petroleum Company.

Personnel of the new organization are natives of Mexico, with the exception of Hiermeier. In addition to the new subsidiary, Honeywell also operates companies in England, Belgium, The Netherlands, Sweden and Canada.

Cunningham Named Manager Of J. P. Devine Company Plant

John F. Cunningham, Jr., has been named manager of the J. P. Devine Company plant at Mount Vernon, Illinois.

Cunningham

Cunningham formerly was research engineer and manufacturing division engineer for Elliott Company, Jeannette, Pennsylvania.

He was graduated from Dartmouth College and from Ohio State University, where he received degrees in economics and in mechanical engineering.

Cunningham is a member of the American Society of Mechanical Engineers and the American Chemical Society.

Paris Appointed to Handle New Dresser Industries Line

L. E. Moffatt, assistant to the general manager, Dresser Manufacturing Division, Bradford, Pa., has announced appointed of Henry H. Paris as exclusive distributor for the new Dresser line of seamless welding ells and fittings in Texas, Arkansas and Louisiana. Paris maintains his office and warehouse at 1125 Rothwell Street, Houston.

For the past 20 years, Paris has sold to jobbers in the Southwest oil fields. The addition of the Dresser line of welding ells will serve to round out his line of welding fittings and flanges.

Col. Higgins Vice President Of Rockwell International

Col. A. E. (Cappy) Higgins has been named vice president of Rockwell International Corporation, New York, it has been announced by A. J. Kerr, vice president of Rockwell Manufacturing Company, Pittsburgh, the parent concern. Col. Higgins, recently retired from the Army, had been associated with the Rockwell organization from 1937 to 1942.

Higgins will maintain his headquarters in the Empire State Building, New York, and will have responsibilities in the export marketing of products of the various Rockwell divisions, and will also be assigned special duties in domestic marketing activities.

Col. Higgins joined the U. S. Army in 1915, served in the Villa Expedition in Mexico, and overseas in World War I.

In 1927 he left the Army to become field promotion man for the American Gas Association and in 1931 was made secretary of the Natural Gas Department of the AGA. He resigned in 1937 to

join the Pittsburgh Equitable Meter Division of Rockwell Manufacturing.

Col. Higgins re-entered the service in 1942, serving as commanding officer of Love Field in Dallas and the air base at Palm Springs, Calif. His last post was as commanding officer of Hickam Field, Pearl Harbor, Hawaii.

As a civilian, Col. Higgins was widely known as an airplane pilot with well over 5000 hours of solo flying. He also gained prominence through his assistance to colleges in establishing gas engineering courses.

Dunlop Named Research Head For Monsanto at Texas City

Richard D. Dunlop, associate director of research at Monsanto Chemical Company's Plastics Division at Springfield, Mass., has been named technical director in charge of research and development of the company's Texas Division, with headquarters at Texas City, effective September 1, it has been announced by Joseph R. Mares, general manager of the Texas Division.

Dunlop

Dunlop, who received a B.S. degree in chemical engineering from Washington University, St. Louis, in 1931 and an M.S. degree in 1933, joined Monsanto in 1927 as a laboratory analyst. In 1933 he became a chemist at the John F. Queeny plant at St. Louis, and in 1938 he became production superintendent of the subsidiary Shawinigan Resins Corporation at Springfield.

Dunlop was transferred to the Plastics Division in 1939 as assistant director of research and became associate director of research in 1944. From December, 1946, to March, 1947, he served as technical investigator for the Department of Commerce in occupied Germany.

Dr. R. M. Hitchens has been named research director of the Monsanto Chemical Company's organic chemicals division. Associate director since 1944, Hitchens succeeds Dr. Lucas P. Kyrides, recently resigned.

Dr. O. J. Weinkauff, assistant director, was promoted to associate director, and Dr. F. B. Zienty and Dr. L. L. Fellinger, group leaders, were promoted to assistant directors.

Dr. Hitchens joined Monsanto in 1931 after receiving a Ph.D. degree from the University of Michigan in that year.

New Ontario Representative

Fisher Governor Company announces the appointment of G. W. Beecroft and Company, Toronto, as sales representative for the Province of Ontaria. Beecroft, who was a colonel with the Royal Canadian Electrical and Mechanical Engineers, is a graduate of the University of Toronto and has had experience with International Petroleum Company, Ltd., in South America and in the petroleum industry in Canada.

Representative Named

Simmonds - Folkening Company, 20 North Walker Drive, Chicago 6, has been selected to represent Newark Wire Cloth Company, Newark, New Jersey, in the Chicago territory.

Krebs Named by Liquid Conditioning Corporation

William A. Krebs has been named engineering and sales representative of Liquid Conditioning Corporation, Linden, New Jersey. His territory will include Philadelphia, the area surrounding it, including southern New Jersey and the state of Delaware. He will have headquarters at 1424 Land Title building, Philadelphia 10.

James H. Binger Will Be Active in Sales Work

James H. Binger has been elected assistant to the vice president of Minneapolis-Honeywell Regulator Company, Minneapolis, where he will devote most of his time to sales department work as assistant to Thomas McDonald, vice president in charge of sales.

Commercial Iron Works Selects Representative

The Gordon Z. Greene Company, 2317 East Eighth Street, Los Angeles 21, has been named California representative for Commercial Iron Works, also of Los Angeles, and will distribute the complete line of orifice fittings and other equipment included in the output of the Commercial Iron Works Company.

Flint Steel Company, Tulsa, To Distribute Aristoloy Bars

Flint Steel Company, Tulsa, is now distributing Aristoloy steel bars in its territory. The product is manufactured by Copperweld Steel Company, Warren, Ohio.

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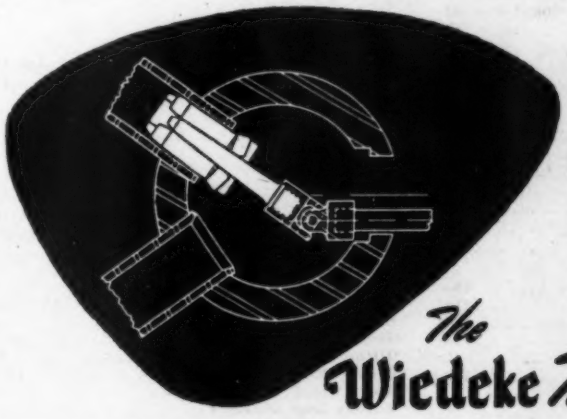

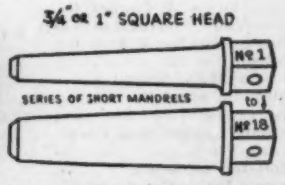

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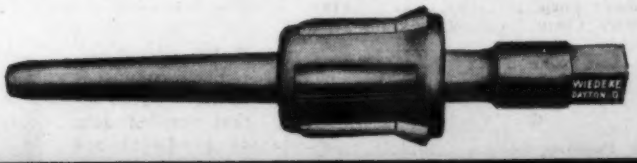

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